



Applied Physics Laboratory
University of Washington
1997 Biennial Report

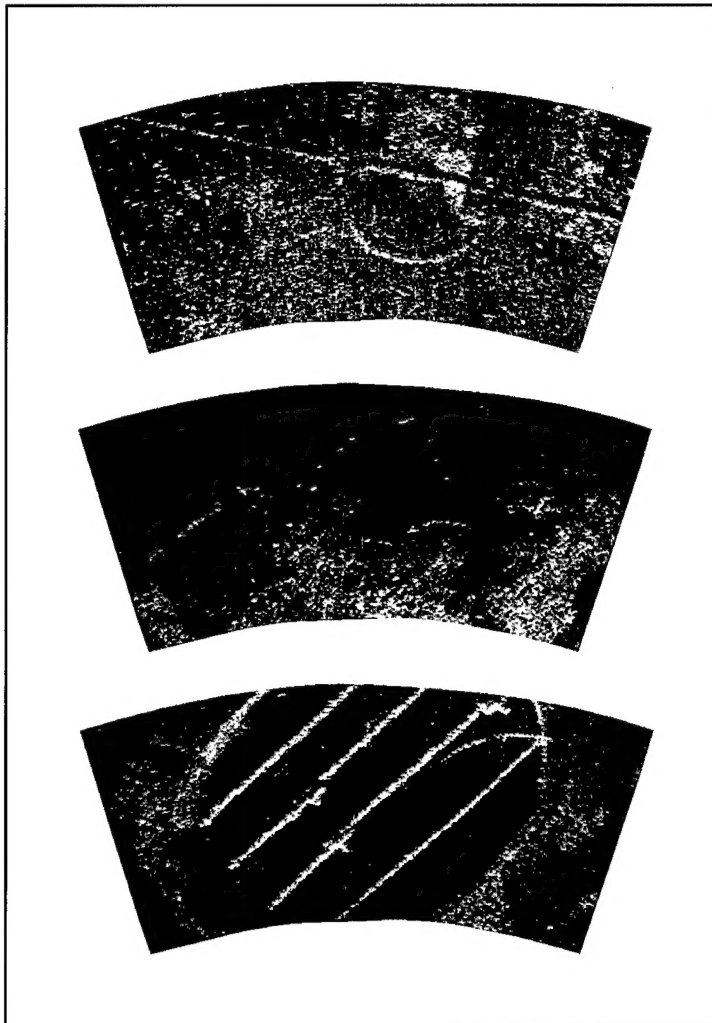
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College of Ocean & Fishery Sciences
University of Washington

1997 Biennial Report

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Cover: Acoustic images of three hull segments approximately 2 ft by 5 ft. The images, taken using the APL-developed Acoustic Barnacle Imaging System in water with 8-inch visibility, reveal a weld bead, peeling paint, and a water intake. See related article on p. 12.

Research Highlights

Taking a Close Look at the Wakes of Surface Ships 11

Ship wakes can offer a deadly pathway for enemy torpedoes. At-sea measurements are helping to better understand the physics of wakes and how they alter sound propagation.

The Acoustic Barnacle Imaging System: Picturing Barnacles with Sound 12

Navy divers often face murky darkness underwater when inspecting the hulls of ships for damage and fouling. An APL system produces clear images of hulls even in the most turbid conditions.

Arches in the Water 14

The ability of ancient Roman arches to distribute compressive forces uniformly was part of the inspiration behind the Virtual Mooring, a new instrument that could revolutionize oceanography.

The Knight Inlet Experiment 16

The oceanographic phenomenon of solibores, energetic internal waves powerful enough to disrupt naval operations and shut down oil-drilling rigs, was studied in Knight Inlet in British Columbia.

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Satellite microwave emission data are helping to answer some of the questions surrounding the Greenland and Antarctic ice sheets. Ice-sheet behavior is an important component of global climate change.

The Underwater Sound of Rain 20

Rainfall at sea is an important yet difficult-to-measure environmental parameter. A method that uses the underwater acoustic signature of rain to measure rainfall rates could help fill this data gap.

Medical Ultrasonics 21

Research is under way on the therapeutic uses of high-frequency sound waves. A portable ultrasound device that will halt internal bleeding is being developed.

Acoustic Shimmer Reveals Hydrothermal Vents 24

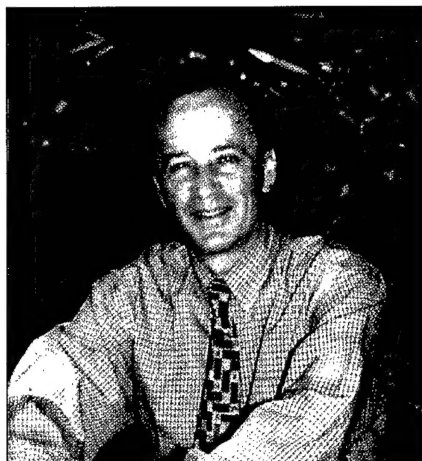
APL expertise in acoustic imaging is being applied to identifying and mapping fields of underwater hydrothermal vents in the North Pacific Ocean.

Towers Beneath the Waves 26

Two fifteen-meter high towers were deployed in the North Atlantic to study the effect of oceanographic conditions on synthetic aperture sonar systems.

Adapting Sonar to the Ocean Environment 28

Achieving the best performance possible from shipboard sonar systems is the goal of the Sonar Environmental Parameters Estimation System.



Dorothy Lowell

Robert C. Spindel

The Applied Physics Laboratory is changing. Driven first by World War II and then by the Cold War, almost the entire history of the Laboratory has been devoted to making the U.S. Navy the best in the world. Our historic focus was on undersea and anti-submarine warfare (ASW), with major programs in basic oceanographic research, torpedo sonars and guidance systems, ASW targets, and underwater tracking and calibration ranges. Today there is no Cold War, and the confusion and turmoil in national policy and military strategy that accompanied its cessation has given way to a clearer vision of what changes must be made to cross the bridge into the very different and largely unanticipated world order of the new century. These changes are necessarily affecting APL's people and programs.

Our success in meeting the challenges of change has been due to the vision, resilience, leadership, innovation, and just plain hard work of all the members of the APL team—scientists, engineers, technicians, machinists, students, accountants, administrators, support staff—and the families that back them at home. I take this opportunity to express once again, as Director, my appreciation and thanks to each and every APL staff member, and also to the extended APL family—our sponsors, Board members, friends, and colleagues. As a result of your efforts,

we are a strong organization even as we enter the latter part of a decade that has been difficult for those in the defense industry. The articles in this report illustrate that APL is a vital contributor to the nation and the university in a variety of old and new ways.

Late in 1996 we engaged in a strategic planning process with the aim of identifying new opportunities that build on our strengths. It resulted in focusing on several initiatives. One, medical ultrasound, is an area in which we have already made a substantial investment and have been rewarded with considerable return. We have now a strong, internationally recognized group of researchers and a modern well-equipped laboratory for physical acoustics research and development. We have several groundbreaking programs joint with industry and with the university's medical school, spearheaded by Larry Crum, and pioneering efforts in sonochemistry, led by Tom Matula. The *Medical Ultrasonics* article describes some of these exciting activities.

Another thrust is air-sea interaction and remote sensing. It builds on a gradual development of APL expertise which today has reached impressive proportions and diversity, and includes Bill Plant's fundamental work on radar scattering from the sea surface, aimed at correct interpretation of wind and wave parameters derived from satellite-borne scatterometers; Andy Jessup's innovative observations of the ocean's thermal skin using extremely sensitive infrared sensors; and Kathie Kelly's studies of ocean circulation, using satellite altimeter data. The *Underwater Sound of Rain* article describes the work of Jeff Nystuen, a member of the remote sensing group, who is developing a new instrument to measure rainfall over the ocean, one of the most poorly known parameters in many global models.

A third focus area is an expanded role in education, not only within the university, but also in K-12 schools, the

general public, and the Navy. Here we will exploit a set of technologies and methodologies developed or adapted by APL for Navy applications. We will capitalize on our unique experience in translating highly complex oceanic and atmospheric environmental information into a product useful to a system developer, a mission planner, or a war fighter. In 1997, together with Washington Sea Grant, we issued our first product for the general public, a multimedia CD-ROM called *The Sound*. With it one can explore the plants and fish, the economy and culture, the meteorology and geology, and the habitats and wetlands of the more than 36 cubic miles of water and 1332 miles of shore that define Puget Sound. The disc was distributed to schools throughout Washington State and is available for sale to the public. We are considering developing a similar educational disc based on the unique expertise of APL's Polar Science Center, and we are currently developing a CD-ROM trainer for the APL-produced BQH-9 submarine recording system.

Although we are changing, we have by no means abandoned our historical areas of expertise, nor have we deviated from our major focus on national defense and the U.S. Navy. We intend to continue our role of helping make our Navy the best in the world and in keeping it that way. In this connection, another new Laboratory initiative is the development of a major facility that will allow decoding and processing of classified as well as open-source data streams and databases, using APL's specially developed tape and signal processing systems and our extensive simulation capabilities. Further examples of our focus on the Navy are given in the articles *Adapting Sonar to the Ocean Environment*, which describes Greg Anderson's work on the Sonar Environmental Parameters Estimation System, and *Taking a Close Look at the Wakes of Surface Ships*, which discusses Jim Luby's studies of

FROM THE DIRECTOR

ship wakes in the context of wake-following torpedoes. While both of these studies follow along lines of traditional APL expertise, two others are indicative of both stability and change. A system designed by Ed Belcher, described in *The Acoustic Barnacle Imaging System: Picturing Barnacles with Sound*, and Kevin Williams' and Frank Henyey's studies on the synthetic aperture sonars that the Navy is developing for mine hunting, described in *Towers Beneath the Waves*, are projects that are obviously for the Navy but, for APL, are forays into new areas of warfare and research.

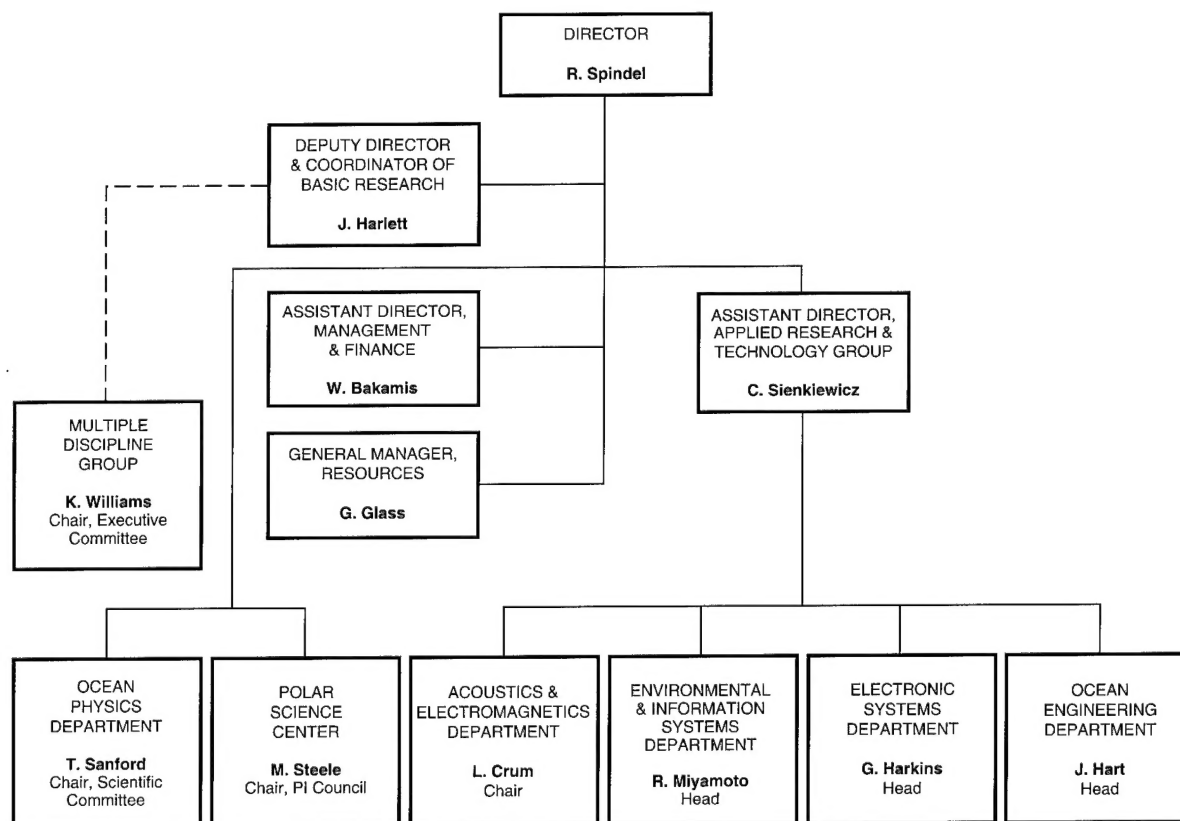
A thorough understanding of the basic principles of science and physics provides the foundation for flexibility in meeting an uncertain future. These last half dozen years have seen an even larger part of APL devoted to basic research in ocean acoustics, ocean physics, and polar science. These areas now comprise more than half our total pro-

gram. In the tradition of fundamental process studies are Eric D'Asaro's work on solibores, explained in *The Knight Inlet Experiment*, and Dale Winebrenner's research on ice-sheet parameters, discussed in *Space-Based Views of the World's Great Ice Sheets*. The former is concerned with the important mechanisms of ocean mixing, the latter with global climate change.

Finally, another illustration of how we have changed and how we have not is Jim Osse's exciting Virtual Mooring project. It follows a long APL tradition of developing new and innovative ocean instrumentation. Moreover, it is the latest in a remarkable history of APL's contribution to the technology of unmanned, autonomous, underwater vehicles, starting with the first one in the world, SPURV. The Virtual Mooring is an underwater glider, propelled by changing its buoyancy to rise and fall, and its center of mass to orient itself with respect to prevailing currents.

Its ability to rise and fall in an almost stationary location effectively synthesizes an anchored ocean mooring.

Two years ago, in the 1995 Biennial Report, I said that APL's solid base in fundamental science, our enviable engineering competency, our in-depth understanding of Navy defense issues, and our proven ability to translate physics into application would serve us well in meeting the challenges of unprecedented national and global transformations. The last few years have shown this to be the case, but more importantly, they have shown the remarkable talent and dedication of the people who "are" APL. They are people who, as Swinburne has written, "...move with the moving ships, change as the winds change, veer in the tide" when required, but who also "stay the course" if that is the correct, but not necessarily the most expedient, path. ■



THE APPLIED PHYSICS LABORATORY

Formed in 1943 in response to a Navy request for assistance in developing a reliable torpedo influence exploder, the Applied Physics Laboratory (APL) of the University of Washington has evolved into a well-known and respected source of research and development in marine-related science and engineering. The partnership with the Navy that began over 50 years ago continues today with a program based in fundamental research and grounded by expertise developed over years of working on Navy problems. Basic research includes ocean physics, polar oceanography, remote sensing, and ocean and physical acoustics, all of which draw upon the Laboratory's demonstrated expertise in designing and deploying specialized instrumentation. This fundamental research underpins and facilitates applications to real-world problems, which range from medical imaging to ice-sheet behavior to measuring rainfall at sea. The articles selected for inclusion in this report give just a sampling of a program that, at any time, may comprise hundreds of individual projects

A research unit of the College of Ocean and Fishery Sciences, the Laboratory is located in Henderson Hall on the campus of the University of Washington. Full-time staff number approximately 200, including 130 scientists and engineers. APL staff collaborate closely with University faculty, and 27 currently hold faculty appointments. Most of these supervise graduate students.

The Laboratory is equipped with a machine shop, a library, and publication facilities. Computing needs are addressed by a combination of special purpose machines, central facilities, and networked personal computers and workstations. Special laboratories are available for microwave remote sensing, image processing, transducer development and testing, electronic system development, and physical acoustics. The Laboratory's two research vessels, including a self-pro-

pelled acoustic test facility, operate from a marine facility on nearby Lake Union. Access to Puget Sound and deep water is available through a system of locks.

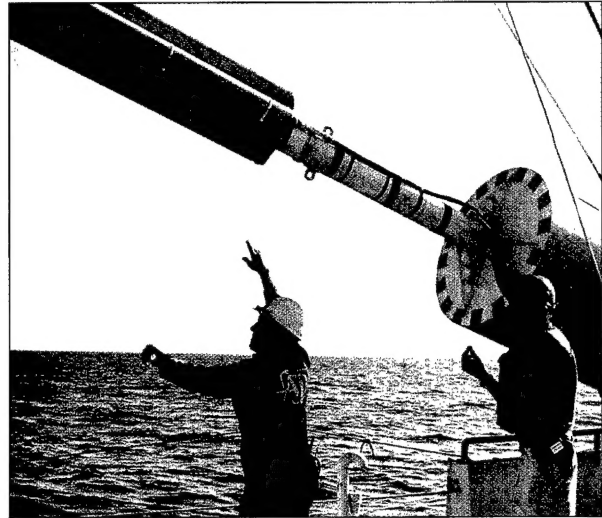
The Applied Physics Laboratory is funded entirely by grants and contracts, receiving approximately three-fourths of its support from Navy sponsors. Other major sources of funding include the National Science Foundation, the National Aeronautics and Space Administration, and the Defense Advanced Research Projects Agency.

Ocean Physics

The Ocean Physics Department (OPD) has an international reputation for excellence in physical oceanography and ocean acoustics research. An aggressive program of instrument development and ocean measurement, combined with data analysis, theory, and numerical modeling, is applied to understanding heat fluxes, ocean currents, waves, turbulence, and mixing. Understanding the relationships between ocean acoustics and physical oceanography is an important focus for OPD.

Six OPD researchers hold joint appointments in University of Washington academic departments, teach and train graduate students, and serve as Principal Investigators on research projects funded primarily by grants from the Office of Naval Research (ONR) and the National Science Foundation (NSF).

OPD scientists and engineers design and build advanced instrumentation to collect data from under the ice, along the coastlines, in estuaries and straits, and in the deep oceans of the world. During the summer of 1997, funded by



Le Olson on deck during the Synthetic Aperture Sonar (SAS) experiment.

NSF, OPD's Absolute Velocity Profiler (AVP) and Modular Microstructure Profiler (MMP) explored an escarpment and submarine canyon off the California coastline to study abyssal internal waves and mixing. The AVP is a freefall profiler which measures currents and water properties in the ocean. The MMP relays vertical microstructure measurements through a twisted-pair cable (tether) for real-time, ship-board display.

Other OPD-developed instrumentation includes the Shallow Water Integrated Mapping System (SWIMS), which collects complementary horizontal measurements and is towed from the stern of a moving ship. It has mapped the formation of large, breaking internal waves and eddies generated along the irregular topographical features of Puget Sound's Admiralty Inlet.

The Deep Lagrangian Float (DLF) tracks the three-dimensional movement of water parcels from the near surface to the deep ocean. This instrument was deployed in the winter of 1997 in the North Atlantic as part of the Deep Convection Accelerated Research Initiative sponsored by ONR to study open-ocean deep convection, an important but poorly understood component of oceanic circulation.

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Close collaboration between theorists and experimentalists strengthens OPD's research. Numerical and analytical models developed by OPD scientists predicted the relationship between internal gravity waves and energy dissipation and mixing. The prediction was verified using measurements made by OPD instruments, and these results were later corroborated by other research groups. The 1995 "solibore" experiment, conducted in Knight Inlet, British Columbia, Canada, used SWIMS and MMP and tested new OPD theories that solibores (internal solitary waves with distinctive remote-sensing signatures) draw energy from the larger-scale circulation and produce substantial mixing.

Several OPD scientists participate in the Multiple Discipline Group (MDG), which unites scientists from many disciplines and departments within APL and the University of Washington to study a variety of scientific problems. The MDG Synthetic Aperture Sonar (SAS) experiment was a 1996 effort to learn more about how internal waves and turbulence affect the propagation of acoustic signals. The Acoustilink electronics, an innovative data acquisition system, was designed and built at APL to meet the needs of the SAS experiment, as well as future ocean acoustics experiments.

Another area of interest for OPD scientists is bubbles, for clouds of bubbles have a profound effect on acoustic signals in the ocean. In response to the Navy's developing interest in shallow, coastal waters, OPD scientists have participated in a variety of "bubble studies," most recently in the near-shore surf off California.

Polar Science

Research in the Polar Science Center (PSC) focuses on observing and modeling the physical processes that control the nature and distribution of sea ice, the structure and movement of high-latitude oceans, and the interactions



Components for the Deep Lagrangian Float were produced in the APL machine shop.

between air, sea, and ice. The Center, which had its origins in the multiyear Arctic Ice Dynamics Joint Experiment (AIDJEX), a major program conducted during the 1970s, has become a leader in Arctic and Antarctic remote sensing, ice dynamics, polar oceanography, and polar logistics.

The relationship between polar regions and the global climate system is of particular interest. PSC scientists have taken major roles in international research programs involving process studies and large-scale observations, including the Marginal Ice Zone Experiments (MIZEX), the Coordinated Eastern Arctic Experiment (CEAREX), the Lead Experiment (LEADDEX), and the U.S./Canadian Arctic Section. Staff are currently in leadership positions in the International Arctic Buoy Program, the Surface Heat and Energy Balance of the Arctic (SHEBA) program, the Climate System Model (CSM) effort at the National Center for Atmospheric Research, the Scientific Ice Expeditions (SCICEX) U.S. Arctic Submarine program, and the World Climate Research Program.

The Center has developed a variety of instruments for collecting meteorological and oceanographic data in the polar regions. A small autonomous vehicle has obtained salinity and temperature data beneath the ice which show the horizontal structure of mixing on scales not measurable by conventional techniques. The Polar Ocean Profile buoy automatically measures ocean temperature and salinity, air

temperature, and barometric pressure and transmits the data through a satellite link. Another instrument, the Freeze-In Buoy, is deployed in a crack (or lead) in the pack ice to capture the earliest stages of ice growth and heat exchange. The Upward Looking Sonar, attached to a bottom mooring, measures the draft of the ice above it. Several of these sonars are monitoring ice thickness in various regions of the Arctic.

Model development is focused on understanding and predicting the air-sea-ice system. Included are studies of mesoscale and large-scale ocean circulation kinematics, dynamics, and thermodynamics, statistical properties of sea ice, boundary-layer processes in the atmosphere and ocean, atmospheric radiation, ocean convection, and coupled system behavior. The modeling work—which uses newly acquired data for model initialization, forcing, and validation—contributes to understanding how the polar regions interact with world climate.

Satellite remote sensing techniques are particularly important in inaccessible regions like the poles. A major initiative in this area is POLES (Polar Exchange at the Sea Surface), an interdisciplinary investigation supported by NASA's global change program, the Earth Observing System (EOS).

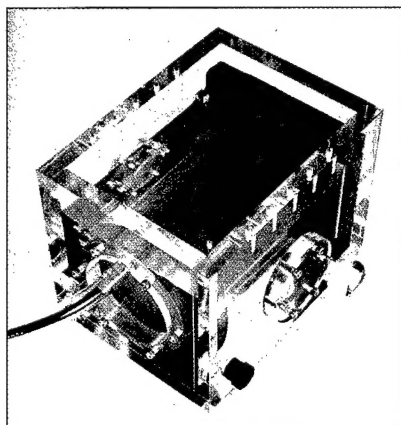
APPLIED RESEARCH & TECHNOLOGY GROUP

The Laboratory's Applied Research & Technology (AR&T) Group comprises four interrelated departments with expertise in physical and ocean acoustics, signal processing, computer simulation, tactical oceanography, electronic systems, and ocean engineering. The AR&T Group applies research results to solve real-world problems. The programs complement and support work by the Navy Research and Development Centers, national research agencies, other university laboratories, and industry.

Acoustics & Electromagnetics

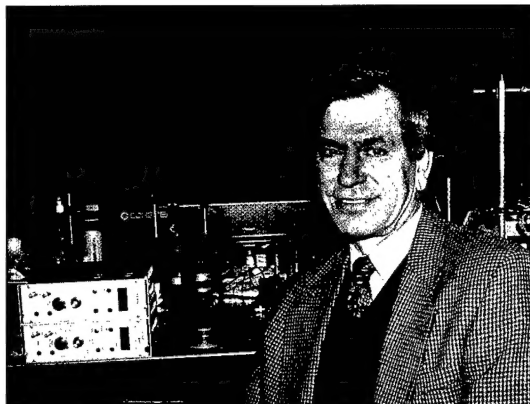
The Acoustics and Electromagnetics (A&E) Department's basic and applied research programs cover a wide range of acoustic and electromagnetics topics.

There are several programs in ocean acoustics. Research in boundary scattering includes theory, experimental studies, and modeling of acoustic interaction with the sea surface and seafloor. High-frequency acoustic experiments are used to study sea-surface scattering and near-surface bubble loss, to gather bistatic scattering measurements of the bottom, and to image bottom properties such as biological and hydrodynamic effects and the penetrability of various bottom types. These measurements, and the models they help refine, are of interest to the torpedo and mine warfare communities. Applied versions of the models are documented in an APL high-frequency models handbook (APL-UW Technical Report 9407) used by researchers in the United States, Canada, the United Kingdom, France, Italy, and Australia.



A high-intensity focused ultrasound (HIFU) test tank used in the acoustic hemostasis project to study the effects of HIFU on blood and tissue.

The Department is a principal contributor to a broadly based effort to show that long-distance underwater acoustic transmissions can be used to calculate and evaluate trends in average



Acoustics and Electromagnetics Department Chair Larry Crum.

ocean environmental parameters. The Acoustic Thermometry of Ocean Climate (ATOC) program has established acoustic transmission and reception sites in the Pacific Basin and has produced sufficient data to demonstrate the concept's potential use in evaluating global warming.

A related program, North Pacific Acoustic Laboratory (NPAL), is funded by the Office of Naval Research and uses the ATOC system to conduct fundamental research for Navy-related objectives, namely, understanding the basic physics of low-frequency, broadband propagation and the effects of environmental variability on signal stability and coherence. In particular, NPAL focuses on three-dimensional wavefront coherence, on the details of signal energy redistribution through mode scattering, on signal and noise variability on ocean-basin scales, and on environmental processes such as internal waves that can affect long-range coherence.

Physical acoustics research is being conducted in the fields of medical ultrasound, sonophysics, and sonochemistry. High-power ultrasonics are being used to study the role of cavitation in extracorporeal shock-wave lithotripsy, a technique employed to destroy kidney and gall stones. This research will result in a better understanding of stone destruction mechanisms, which will lead to more effective

treatment schedules and power dosages.

Under development in a collaborative program with an industry partner is a portable, hand-held acoustic imaging device that will detect internal bleeding in trauma patients. Complementing this program is a five-year study, undertaken with University of Washington health science departments, on the use of ultrasound to image the bleeding

site and to deliver focused ultrasound to the region to halt blood loss. This approach has potentially wide applications in military and civilian medical settings.

Research is also under way on sonochemistry, where high-intensity ultrasound is employed to influence chemical reactions. In related work, the intriguing physics associated with single-bubble sonoluminescence, a phenomenon that may involve temperatures of millions of degrees, is being examined.

A variety of remote sensing techniques are being used by A&E scientists in their studies of the Earth's atmosphere, oceans, and climate. Microwave and infrared techniques are applied to investigations of the sea surface from aircraft and satellites. Wave-tank work is also undertaken to better understand the mechanisms important to sensing the sea surface. Satellite applications of microwave techniques in systems such as synthetic aperture radars, scatterometers, and altimeters are investigated and utilized in studies of sea-surface processes important to the Earth's climate. New aircraft-based techniques are being developed to allow the remote measurement of winds, waves, currents, coherent atmospheric turbulence processes, and microscale wave breaking. The latter process is important in gas transfer at the air/sea interface.

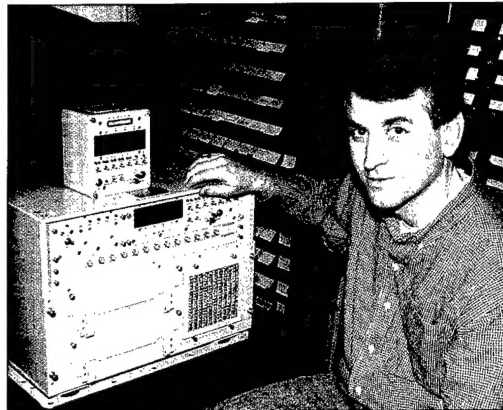
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Included on the applied side of the department's work is support for the U.S. Navy's Integrated Undersea Surveillance System (IUSS) Improvement Program, which will provide a new design and an operational demonstration of an autonomous power supply and signal detector system for IUSS. This front-end upgrade to the existing Shore Terminal Equipment Group takes advantage of digital technology and microprocessor controllers to afford autonomous operation and full control from remote sites. In comparison with present fleet systems, this new system will greatly reduce maintenance and the need for spare parts. Its performance was demonstrated successfully in a side-by-side comparison with existing equipment conducted in April 1997.

Electronic Systems

For more than 25 years the Electronic Systems (ES) Department at APL has provided state-of-the-art solutions to applied Navy needs in the areas of shipboard data collection, noise monitoring, signal processing, underwater tracking ranges, acoustic transducers, and sonar simulation. To solve problems across this wide spectrum of technologies the Department is staffed with engineers, computer scientists, physicists, and technicians with expertise in custom hardware development, digital signal and image processing, real-time embedded systems, object-oriented programming, acoustic analysis, and graphical user interface development.

Data collection systems built by the ES Department are deployed at sea on many Navy submarines. These systems must provide reliable recording of submarine sensor data in an environment characterized by high humidity, shock, and vibration. The Department has also been involved in the development of a land-based system to process data collected by submarines and other Navy sensors. This land-based system is composed of nearly twenty real-time



Rick Broman with the AN/UNQ-9 tactical data recorder.

subsystems implemented with a combination of custom and commercial VME-based hardware running under the VxWorks real-time operating system. Data are routed between the subsystems via a high-speed fiber optic network centered around an optical crosspoint switch. Overall control of the system is provided by a UNIX workstation which also handles job requests submitted by data analysts over a wide area network.

Acoustic lens technology has been ongoing work in the department for many years. Similar to the way the human eye works with light, an acoustic lens uses a refractive medium (the lens) to focus sound onto one of many small acoustic transducers that populate the lens retina. These transducers play the role of rods and cones in human vision. By using the physics of refraction to provide spatial directivity, the weight and expense of sonar beamforming electronics and software are obviated thus allowing the application of sonar systems in areas where weight, size, and cost were previously prohibitive. Recent acoustic lens projects in the Department include development of hand-held sonars to assist Navy divers with detection and classification of mines in turbid water and inspection of ship hulls for mines and fouling, and development of a Remotely Operated Vehicle (ROV) sonar for obstacle avoidance and navigation.

To support Navy testing of underwater vehicles, the Department develops three-dimensional underwater tracking ranges, a recent example being the SEAFAC noise measurement range in Southeast Alaska. The Department also developed a stand-alone self-noise monitoring system for use onboard Navy submarines.

The Department has been working with the Navy and Marine Corps to solve the difficult problem of detection and classification of mines from

unmanned aerial vehicles. Data from laser imaging systems aboard these vehicles are processed with morphological and other image processing methods. The high data rate and onerous processing required for this task led Department staff to develop custom high-speed processing hardware optimized for the transfer and processing of imagery data.

One of several ongoing simulation efforts in the Department is development of the Sonar Simulation Toolset (SST). The SST allows a sonar developer to synthesize realistic, multichannel active and passive sonar acoustic time-series data for the development and testing of new signal processing approaches as well as for comparative analysis of current operational systems. The SST package has been ported to a wide variety of workstations and provides a powerful, desktop synthesis capability to sonar designers.

As part of recent facility upgrades at APL, several ES Department electronic fabrication rooms have been completely remodeled. In addition, a new classified data processing laboratory for the Department has been constructed. This new laboratory will house data-collection systems, UNIX and PC/NT workstations, a high-speed ATM fiber network, and digital signal processing development hardware.

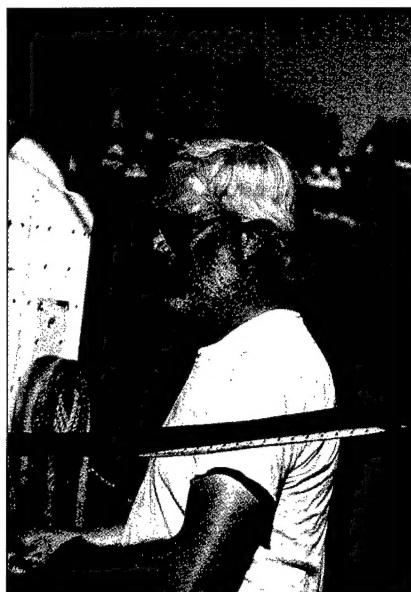
The expertise of Department staff, complemented by modern fabrication and laboratory facilities, provides the basis for the ES Department to support the Navy into the 21st century.

Environmental & Information Systems

The mission of the Environmental and Information Systems (EIS) Department is the intelligent processing of information, beginning with efficient data acquisition and storage, continuing with adaptive signal processing, and concluding with innovative human-to-machine interfaces. The Department's applied research brings together a multidisciplinary group of physicists, earth scientists, computer scientists, signal processors, and interface designers to create new systems and system components that use knowledge of the environment for improved performance and decision making.

Expertise in data acquisition and signal processing is focused on the use of wideband acoustic detection, classification, and modeling for use by torpedo and mine countermeasure systems in the mid-to-high frequencies. Experimental arrays and data acquisition systems have been built to acquire target, propagation, reverberation, and clutter data. New signal processing techniques, such as spatial correlation, wavelets, and morphological processing, are used to reduce interference, improve target echoes, and enhance classification using knowledge of the environment. EIS scientists also use the data to validate models that extend the results to other system configurations and environments.

The Department develops problem-solving systems, such as the scenario controller for the Naval Air Warfare Center, Aircraft Division, at the Patuxent River Naval Air Station. In this case, a sophisticated acoustic test and engineering simulation system lacked a way to easily generate certain



Jim Luby on a test cruise on Lake Washington.

test scenarios. EIS experience in software and physics produced an intuitive, flexible graphical user interface that specifies all information needed to generate synthetic acoustic data (i.e., ocean environmental parameters, vehicle trajectories, and source-radiated noise). When the information is specified, the APL-UW software sends control commands to the real-time hardware and provides an overview of the scenario on a computer color monitor.

Knowledge of acoustics, physics, applied mathematics, and computer science is combined in projects such as the Sonar Environmental Parameters Estimation System (SEPES). This system allows a user to display sonar reverberation data and to choose a segment of the time series. Bottom or surface backscatter and reflection loss information are extracted from the data and displayed as a function of grazing angle. Within this easy-to-use system is a nonlinear optimizer that minimizes the difference between the data and an acoustic model.

Software development has been taken one step further into the domain of intelligent information processing with the creation of a computer-model prototype of a combatant ship operat-

ing at sea in an uncharted, dangerous area. At the heart of this ship is an innovative, object-oriented software toolbox for the storage and management of shipboard environmental data. Unlike conventional databases, the toolbox provides several alternative schemes (e.g., a real-time updated, triangulated mesh that is adaptable to different data types and spatial resolutions) to feed accurate data to tactical decision aids. Attached to the toolbox is a system that extracts bottom backscatter and reflection parameters, among the most difficult, yet critical, environmental parameters for sonar system optimization. As the ship operates at sea it becomes more "environmentally aware" so that its sensor systems can be optimized for the specific time and place. An attached workflow management system "knows" about the data requirements for sonar optimization. Designed with the use of intelligent software agents, the workflow planner breaks down the data requirements into queries that search on the World Wide Web, gather the best data possible for the specified area and time, and bring back the data for improved decision making.

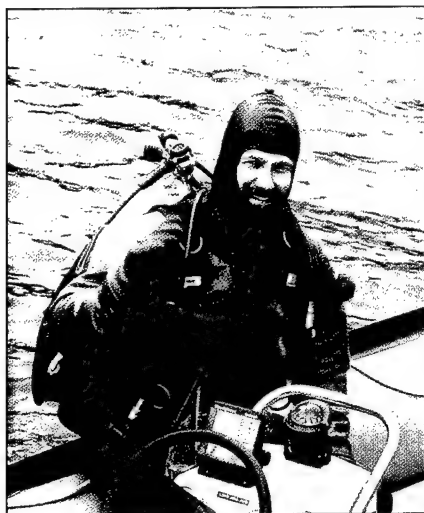
The EIS Department has an ongoing program in interactive multimedia development and a multimedia team that combines high-end graphics, interface design, music, and video to provide a range of products that span audiences from kindergarten to the U.S. Navy. For the Navy, the team produced interactive multimedia CD-ROMs for environmental information critical to improving pre-mission planning. Also being built is a system that uses and maintains specialized, acoustic data-collection hardware aboard submarines. For the local Seattle-area community, the multimedia team produced and distributed "The Sound." Available through Washington Sea Grant, "The Sound" is a CD-ROM that combines entertaining, informative screen design with fundamental science. Users explore the Puget Sound region's geology,

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biology, oceanography, and weather and learn about the interaction of these factors with water quality, the economy, and recreation.

Ocean Engineering

Hands-on experience at sea is a hallmark of the Laboratory, and the Ocean Engineering (OE) Department, where much of this expertise resides, is a resource to APL and the Navy.



Mike Welch prepares for a dive to test equipment in Puget Sound.

Department engineers have extensive experience in the design, fabrication, and deployment of complex systems in the deep ocean and in coastal waters. In a recent project, the department provided engineering support for studies of acoustic and physical sea-floor properties in the coastal zone. This work involved deployment of a large APL-designed instrument platform that rests on the bottom, with sensor arrays tethered to a ship positioned in a four-point moor. The project was a collaborative effort with the Naval Research Laboratory and the Defence Research Agency of the United Kingdom. The environmental acoustic

data are applicable to mine warfare planning.

APL pioneered the development of an unmanned underwater vehicle for taking scientific measurements and has continued to use such systems to gather data in unique environments. Working with the Polar Science Center, the OE Department developed a small autonomous vehicle that has made over 70 runs during the past five years to gather conductivity-temperature-depth (CTD) data under the Arctic ice. There have been 20 successful deployments of an OE-developed variant of the vehicle that deploys a light line for several thousand feet to assist in placing instruments between ice holes more than 1000 meters apart.

In another project, APL is providing the engineering expertise and fabrication skills to develop a unique profiling conductivity-temperature-depth (CTD) glider. Conceived in the UW School of Oceanography, the virtual mooring device is an autonomous underwater vehicle containing sensors that measure and record a continuous profile of conductivity and temperature as the instrument glides between the surface and a depth of two kilometers.

Position at the end of each profile is determined by an onboard Global Positioning System receiver, and bidirectional communications are provided by a cellular phone link. Use of the



Jim Osse, Peter Sabin, and Mike Ohmart holding the APL-developed Autonomous Line-Dispensing Vehicle (ALDV) at Ice Camp Knossos, Lincoln Sea, north of Greenland.

coming satellite-based, worldwide cellular phone network will allow users to review the data collected and modify the sampling strategy or location.

The department also has a program for evaluating corrosion and failure of components on Navy submarine, surface-ship, and bottom-mounted sonar systems. Program team members inspect cables, connectors, and transducers, autopsy in-service components, test and autopsy newly designed components, identify failure modes and mechanisms, and recommend solutions. Video documentation provides an instantaneous, permanent record that elucidates cause, effect, and corrective action for program managers, field service personnel, and Fleet operators. ■

Taking a Close Look at the Wakes of Surface Ships

As a ferry crosses Puget Sound, a bubbly wake churns out behind the ship, leaving a foamy trail through the water. The wake forms when air is injected into the water from the spinning propellers and from bow waves moving outward from the hull.

Similarly, a military vessel generates a foamy trail, but its wake may offer a deadly pathway for enemy torpedoes capable of locating a wake and following it to the ship. To counter this threat, surface-ship defense programs are considering anti-torpedo torpedoes equipped with acoustic sensors that can detect and attack an approaching torpedo in the wake. The key to success is understanding the conditions within a ship's wake and how they affect the propagation of sound.

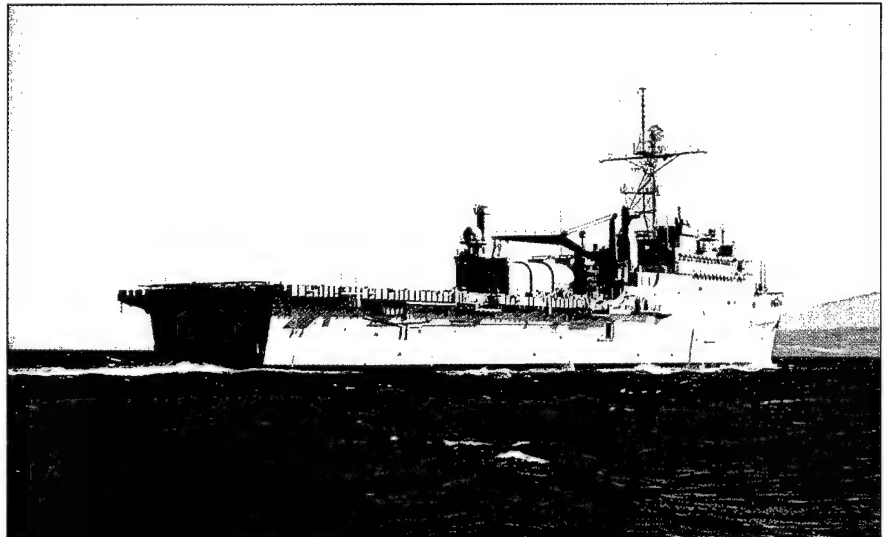
Bubbles interfere

Two acoustic phenomena can interfere with an anti-torpedo torpedo's acoustic sensing ability. One is backscattering: Bubbles are strong reflectors and may scatter underwater sound, effectively blocking the sonar pings. The second phenomenon, absorption, occurs when bubbles and chemicals in the water absorb sound energy. It is known that certain sound frequencies are less affected by these phenomena than others, and that sensors may be set to the frequencies that allow "seeing" most effectively through the wake.

In the summer of 1996, as part of a multilab effort to find the optimum frequencies for counterweapon sensors, the Laboratory participated in a cooperative experiment with the United Kingdom where two complementary wake measurement systems were deployed. Undertaken at the Canadian

Forces Maritime Experimental and Test Ranges Nanoose tracking range in British Columbia, Canada, and funded by the U.S. Navy's Joint United States/United Kingdom Surface Ship Torpedo Defense Program Management Office (PMO 427), the experiment brought together teams of scientists from APL, led by Principal Engineer James C. Luby, and the United Kingdom's De-

smaller vessels, measuring the wake's acoustic properties by two different methods. One, an inverse method, infers acoustic absorption from measurements of acoustic backscattering. The sensor views the wake from below and provides an image of spatial structure as well as estimates of absorption and backscattering. The other, a direct method, uses pairs of transmitters and receivers, operating at fixed frequencies, that are towed through the wake. Received sound amplitude is compared to transmitted sound amplitude to calculate sound loss per unit of distance.



James Luby

The LPD-10 class amphibious troop carrier laying the wake for the experiment.

fence Research Agency. The Nanoose experiment had been recommended by a joint panel of United Kingdom and United States experts on torpedo defense formed at the request of the U.S. Navy's Program Executive Office, Undersea Warfare.

At-sea experiment

During the Nanoose experiment, an LPD-10 class amphibious troop carrier steamed around the tracking range as British and American scientists crossed back and forth through its wake in two

One of the direct measurement systems used at Nanoose was developed and built by APL. The two experimental methods complement each other favorably.

The Nanoose results provide important information databases, built using the two different methods, that can be correlated with each other to refine simulation models of wakes. Such models allow computer simulations to be used in the design of new weapon systems. ■

The Acoustic Barnacle Imaging System: Picturing Barnacles with Sound

Imagine a fog so thick that your hand disappears from view five inches from your face. Now imagine examining a surface the size of three football fields under such conditions. This is the situation Navy divers face when inspecting the hulls of ships moored in turbid water. The murky darkness commonly found in busy harbors obscures the visual evidence—barnacles, flaking paint, and broken hull fittings—that cleaning or repair is needed.

Hull inspection is a huge task

At many mooring sites where U.S. Navy vessels dock for underwater hull inspections, the water visibility ranges from eight inches to as little as zero. In such unfavorable conditions, visual inspections go very slowly. At the lowest visibilities, divers must rely on their sense of touch to detect fouling, hull damage, and foreign objects. The likelihood of hull damage being correctly characterized under such conditions is low, yet the magnitude of the problem

is huge—a single aircraft carrier has some 3.5 acres of hull in contact with the water. Multiplying this factor by the Navy's fleet of twelve aircraft carriers and adding in the destroyers, cruisers, frigates, and auxiliary ships reveals the scope of the challenge. Although drydocking is sometimes an alternative to in-water inspections, it is very expensive and is not always available, especially during deployments.

One solution in poor visibility environments is to use acoustic imaging systems that rely on sound energy rather than light to produce an image. The Naval Surface Warfare Center (NSWC), Deep Ocean Systems Branch, which is responsible for testing and developing better inspection and hull cleaning technologies for the Navy, put out a request for an acoustic imaging system that could detect fouling and not be hampered by zero visibility conditions. The Naval Explosive Ordnance Disposal Technology Division (NAVEODTECHDIV) suggested that

NSWC test the acoustic lens technology that APL helped develop for the NAVEODTECHDIV program.

Individual barnacles imaged with sound

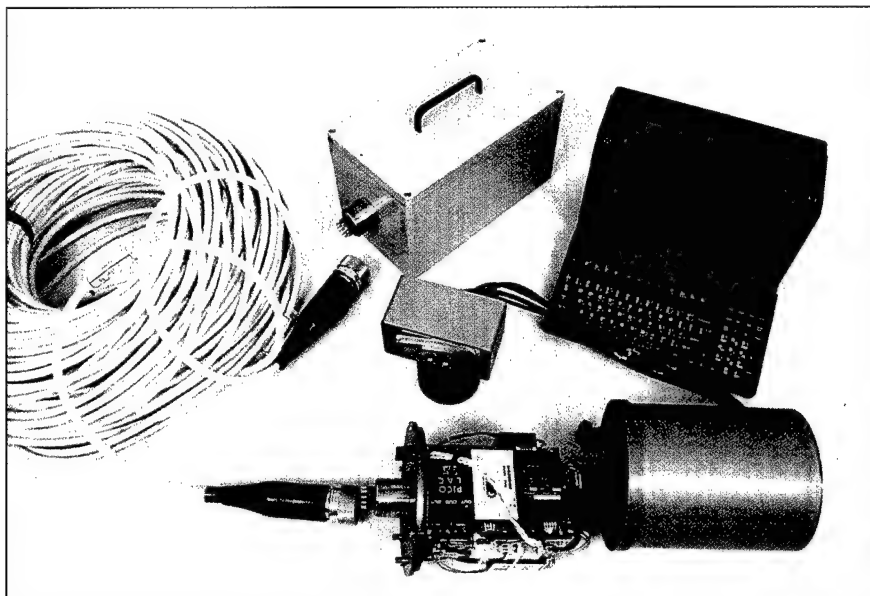
With more than a decade of experience in designing acoustic lenses for underwater imaging, APL Principal Electrical Engineer Edward Belcher led the team that designed the prototype Acoustic Barnacle Imaging System (ABIS). Although no existing acoustic system met the Navy's requirements, the prototype more than met the challenge, imaging not only individual barnacles and barnacle clusters, but also bolts, weld beads, grates, and even flaking paint.

Mounted on a remotely operated vehicle (ROV) and using high-frequency sound, ABIS sends images of the hull to the surface as the system is "flown" beneath the ship. The soundhead consists of four transducer elements made of shaped composite behind polystyrene lenses. The in-water imager connects through 500 feet of cable to a portable computer at the surface that provides topside display and control.

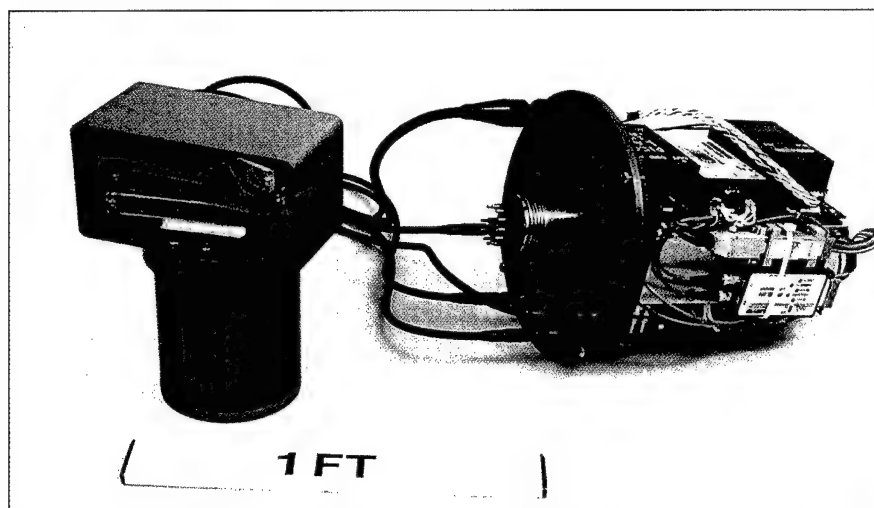


A water intake on the hull of a vessel, imaged at a 7-ft range in 8-in. visibility water. The image shows details of the removable sections of the intake, including individual bolts and bars.

The major components of the Acoustic Barnacle Imaging System: The soundhead is in the center of the photograph. The in-water electronics and its housing are in the foreground. The 500-ft cable, surface breakout box, and portable computer are in the background. The portable computer provides the image, control, and data storage tasks.



Dorothy Lowell



Dorothy Lowell

The soundhead consists of four transducer elements made of shaped composite behind plastic lenses.

Prototype tests successful

Tests of the prototype in water with eight-inch visibility revealed that the system can image a section of hull approximately five feet wide and two feet long in one-half second, and can discriminate objects less than a half-inch apart. The resolution of the ABIS prototype images was high enough to permit not only detection of fouling, but also grading the degree of fouling using a density estimation.

An image of one of the ship's anodes was produced during testing. The anode, approximately one-and-one-half

inches high and three feet long, maintains the hull at a voltage potential that reduces corrosion. Because anodes are relatively delicate and expensive to replace, they are objects to be avoided with ROVs. ABIS imaged the anode very well, and operators had no difficulty identifying and avoiding it.

One of the Navy's requirements was that the ROV carrying the imaging system must be able to operate at speeds of one to two feet per second. Other ROV-mounted acoustic hull-inspection systems typically produce distorted images because the vehicle

moves faster than the sensor can image. The topside operators must resort to the laborious method of stopping the ROV for tens of seconds, gathering an image, moving, and then stopping again before gathering another image. The rapid, half-second rate at which ABIS gathers the data eliminates most of this distortion.

Commercial applications

Although designed for Navy use in support of hull maintenance, ABIS has other applications, including scanning hulls for mines or for containers of illicit materials such as drugs. Its speed and ease of use could be attractive to commercial shippers who cannot afford to have their vessels idle for long periods of time. ■

Arches in the Water

While bicycling through southern France, APL Mechanical Engineer Jim Osse was impressed by the simple, elegant design of the arches in the ancient Roman aqueducts. He wondered if the arch's quality of distributing compressive forces *uniformly* could be incorporated into the pressure vessels used in oceanographic instruments. The vessels are housings that protect electronics packages from being crushed, for as water depth increases so do density and pressure. Glass spheres or thick-walled metal tubes, both of which are strong under compressive stress, are commonly used. Back at APL and inspired by the Roman arches, Osse designed a new pressure vessel—a cylindrical aluminum hull made of arched panels separated by a series of ring frames.

Inherent strength of arches

Built in the APL machine shop with the computer-controlled numerical lathe, this hull was first incorporated into the APL-developed Deep Lagrangian Float, used by Principal Oceanographer Eric D'Asaro in his

studies of the mixed layer of the oceans. The inherent strength of the aluminum arched ring frames and thin wall panels allows the hull to compress without buckling as it descends. As pressure increases, the thin wall panels compress uniformly inward just as a Roman arch would.

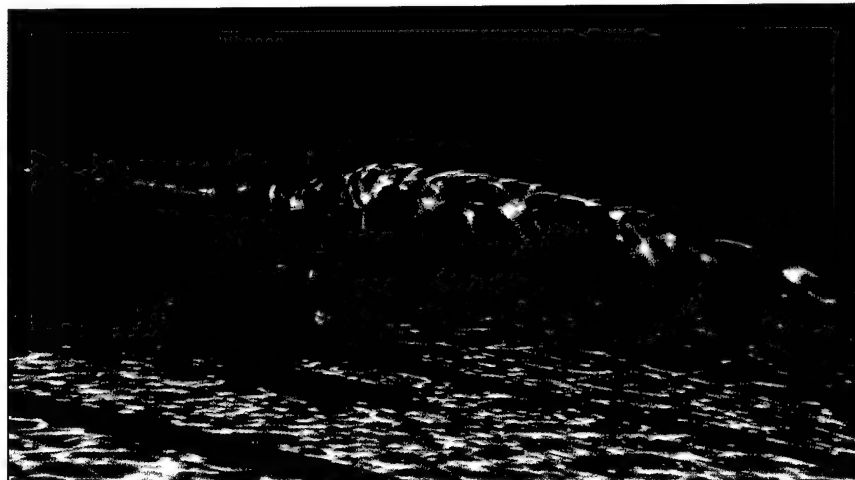
Now, in collaboration with Professor Charles Eriksen of the University of Washington's School of Oceanography, Osse has used the hull in the Virtual Mooring, a new instrument that could revolutionize oceanography. The Virtual Mooring will move up and down

through the water continuously collecting data on the ocean's structure at fixed locations, and will be deployed in geographical networks analogous to the weather balloon network that meteorologists use to probe the atmosphere.

Traditionally, data needed by oceanographers to track ocean circulation have been obtained by lowering instruments on wires from ships or by tethering data-collecting instruments to moored buoys. Both approaches have their drawbacks: ship-collected data are confined to the trackline of the vessel, and ship operating costs are high. Data points are often widely separated by space and time as the ship transits between them. Moored buoys are costly, difficult to deploy, and require expensive ship-time to deploy and recover. Conductivity, temperature, and depth (CTD) instruments hung on a line below a moored buoy offer only limited spatial resolution, and data are recovered only when the mooring is retrieved, often months or even years after they have been recorded.

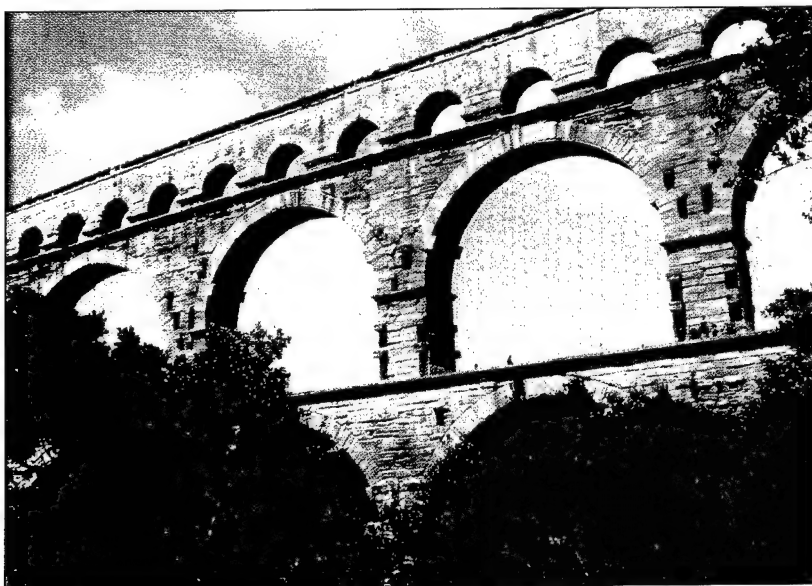
An underwater airplane

The Virtual Mooring is so named because it carries out many of the functions of moored strings of data-collecting instruments, but is a free-drifting autonomous underwater vehicle that



The Virtual Mooring in a saltwater swimming pool during the instrument's first open-water test.

T. James Osse



Ancient Roman arches in southern France provided some of the inspiration for the design of the Virtual Mooring.

T. James Osse

glides through the ocean, propelled by battery-driven changes in buoyancy. Essentially an underwater airplane, the Virtual Mooring glides against, or stems, the prevailing ocean currents while moving up and down to collect data. The instrument is designed to profile hundreds of times through the upper half of the deep ocean over several months while traveling the equivalent of a quarter of the Earth's circumference. Because the instrument determines its geographical location while at the surface by using a navigational fix from the Global Positioning System, the Virtual Mooring can adjust its compass heading and glide slope to move in a different direction and at a different speed during each profile cycle.

At 180 cm in length and 50 kg in weight, the Virtual Mooring offers solutions to oceanographers' historical dilemmas at the relatively inexpensive cost of about \$50,000 per instrument. Real-time data retrieval will occur via a global cellular-phone network, expected to be operational by the end of 1998. This bidirectional network will allow onshore operators to send messages to the instrument so that the Virtual Mooring can be instructed to move to a new sampling location, to a rendezvous with a research vessel for recovery and servicing, or to change its sampling strategy based upon data just received. The goal of the developers is to make possible a network of hundreds of instruments that will provide a real-time, three-dimensional grid of coverage.

Changes in buoyancy provide propulsion

The changes in buoyancy that provide the Virtual Mooring's net propulsive force are controlled by a battery-driven miniature hydraulic pump that shifts oil between an inside and outside rubber bladder. Thanks to the APL-designed pressure hull, called an



T. James Osse

For testing purposes, the APL low-drag hull model was painted black and sprayed with a mixture of kerosene and talcum powder. The white areas near the tail of the model are where the more-efficient laminar flow of the air that exists on the forebody has turned into a high-drag turbulent flow. This "flow visualization" technique confirmed that the hull design produced long runs of laminar flow and very low drag.

isopycnal hull for its ability to mimic the density variations of seawater, the Virtual Mooring's energy efficiency is increased. Most pressure hulls are stiffer than the APL hull—they compress less than an equivalent volume of seawater, gaining relative buoyancy when they descend and losing buoyancy when they ascend. However, the isopycnal hull design requires fewer adjustments for buoyancy (and therefore less energy) as the vehicle takes profiles. Recognizing the uniqueness and usefulness of the arched-panel isopycnal hull, Osse has applied for a patent.

Complementing the Virtual Mooring's arched-panel design is its low-drag hull shape, which allows the instrument to ascend and descend more efficiently, maximizing the amount of data that may be taken before batteries are exhausted. Osse adapted an existing APL low-drag hull shape by adding stubby wings that enable the instrument to glide horizontally. Test runs in the University of

Washington's Department of Aeronautics and Astronautics low-speed wind tunnel revealed that the wing design produced favorable lift-to-drag ratios, allowing the vehicle to fly along gentle glide slopes in order to stem ocean currents efficiently.

In-water testing

The Virtual Mooring project is funded by the Department of Defense through the Multidisciplinary University Research Initiative program on autonomous oceanographic sampling networks administered by the Office of Naval Research. Having confirmed that the combination of low-drag technology and arched hull design is successful, Osse and Eriksen have now completed a prototype. Initial in-water testing has taken place at APL's backdoor: Puget Sound and Lake Washington. Later testing will occur in Jervis Inlet, British Columbia, Canada, and in the Labrador Sea. ■

The Knight Inlet Experiment

The vast reaches of the world's oceans often call oceanographers far from home to collect data. Sometimes, however, the ideal setting for an experiment is practically in one's own backyard. Such was the case for a group of APL oceanographers when they conducted a study of mixing processes in Knight Inlet, British Columbia, Canada.

The experiment was coordinated by Principal Oceanographer Eric D'Asaro, who was joined by colleagues from APL's Ocean Physics Department. Also taking part were scientists from Scripps Institution of Oceanography and the Institute of Ocean Sciences in British Columbia. Knight Inlet was chosen because the circulation patterns are clear and well documented and the working conditions are nearly ideal: the Inlet is a sheltered fjord with little vessel traffic, where many experiment-hampering variables, such as strong winds, can be eliminated.

The solibore phenomenon

Funded by the Office of Naval Research and the Institute of Ocean Sciences, the goal of the three-week ex-

periment was to gain a better understanding of how tidal fluctuations in the Inlet affect stratified flow over a rough bottom. Of particular interest was an oceanographic phenomenon known as a solibore. Solibores occur in shallow-water regions throughout the world when an energetic internal wave forms as tidal currents flow back and forth over rough topography. They can be powerful enough to interrupt naval operations and even shut down the operations of oil drilling rigs.

A solibore is a hybrid of a solitary internal wave, called a soliton, and an internal tidal bore. A soliton propagates internally without changing shape or changing the water's stratification as it passes. A bore is a tidally driven pulse of water that advances rapidly up an estuary and considerably alters the circulation as it moves. Solibores (the term was coined by APL Principal Physicist Frank Henry in 1995) lie on the con-



Eric D'Asaro

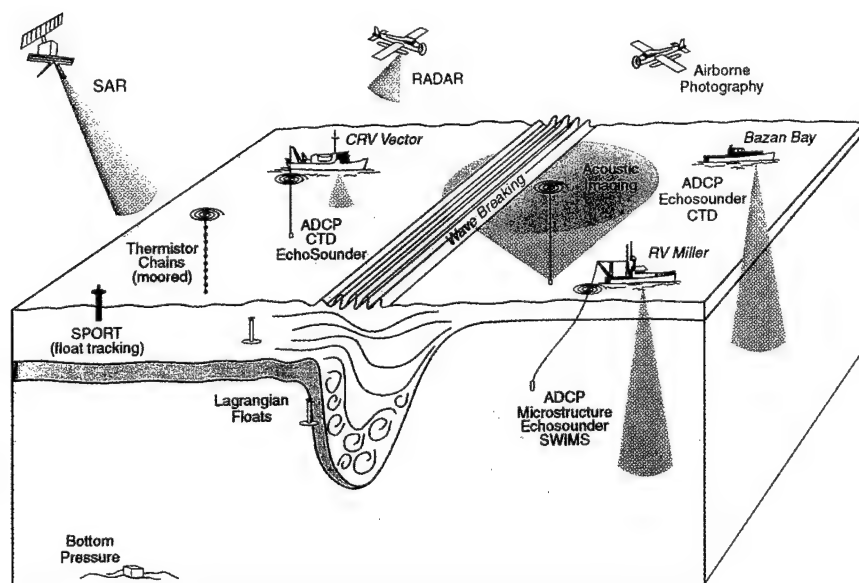
Smooth water, edged by breaking waves, is the surface expression of a solibore in Knight Inlet.

tinuum between solitons and tidal bores.

Solibores are common in Knight Inlet because of the geometry of the basin—a high submarine ridge forms a sill at the seaward edge of the basin. The changes in circulation that occur as the tide ebbs and flows over the sill are powerful and dramatic—deep water is pushed up to a shallower level, distorting and mixing layers normally stratified by differences in temperatures and salinity.

Different types of solibores

The Knight Inlet researchers found many different types of solibores, most of whose existence had been suspected but not confirmed. One type energetically swirled the layers together and injected a big "squirt" of water into one layer, thickening it dramatically. Another type of solibore rapidly deepened the relatively thin layer of surface water, which in some cases increased from 3 meters to 14 meters in as little as 15 minutes. The Knight Inlet work also confirmed that a solibore is not just an isolated event but rather is at the front end of dramatic changes in circulation and mixing.



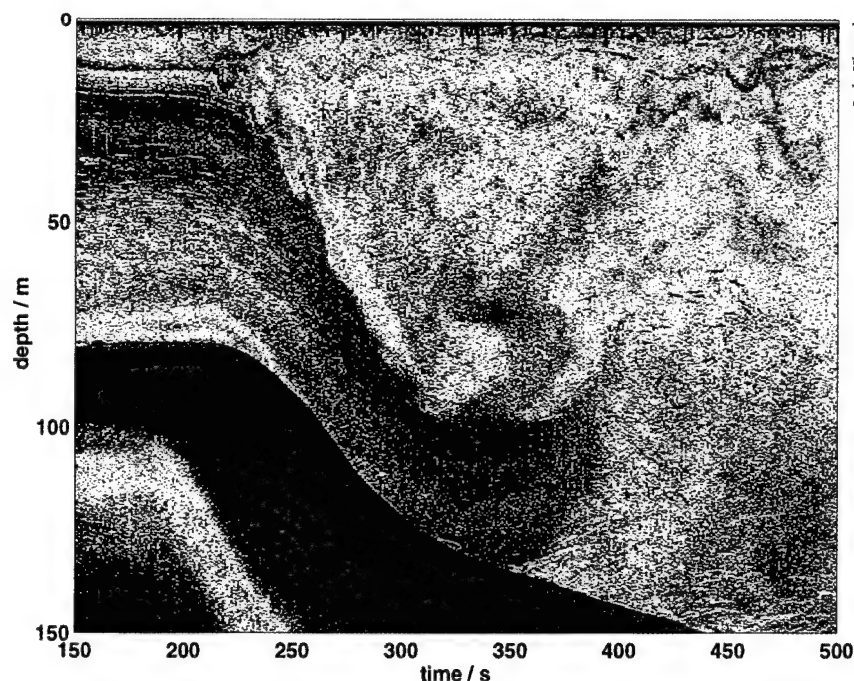
This schematic diagram illustrates the variety of instruments and platforms used in the Knight Inlet experiment. Note the solibore propagating from left to right through the instrument array.

Planes, boats, and instruments

A variety of instruments were used in the experiment. Three boats were equipped with acoustic Doppler current profilers for velocity profiles, while temperature and salinity were measured with thermistor chains and conductivity-temperature-depth instruments. APL's Shallow Water Integrated Mapping System (SWIMS) was towed from the stern of a vessel to rapidly survey velocity and temperature. The Modular Microstructure Profiler (MMP) measured the dissipation of kinetic energy and allowed examination of mixing in great detail. Acoustically tracked Lagrangian floats took direct measurements of the mixing rates and water parcel motions.

Each vessel was equipped with an echosounder, similar to those commonly used on ships to locate the ocean bottom. In the Knight Inlet experiment, however, the echosounders were also used to detect layers of zooplankton that marked layers of water. The mixing generated by solibores was revealed in echosounder images of swirls of zooplankton disturbed from their normally layered patterns.

The suite of instruments captured three-dimensional "snapshots" of solibores and related changes in circu-



Jody Klymak

Mixing caused by solibores is illustrated in this echosounder image. Normally stratified layers of zooplankton (as shown in orange at 50 m depth on left-hand side of image) are swirled together as a solibore passes through (as shown on right-hand side of image at 50–150 m depth.)

lation. Two float planes allowed investigators to go aloft and use synthetic aperture radar and photography to capture the surface expression of the circulation changes from the air. The aircraft were also useful in directing the boats carrying measuring instruments to areas of solibore activity. Experiment coordinator Eric D'Asaro, who had the

fastest vessel, conducted ship surveys that complemented the aerial surveys.

Taken together, the data collected at Knight Inlet provide an unparalleled three-dimensional, multifaceted view of changes in stratified flow within the Inlet. What the investigators learned there is useful even for interpreting older data taken elsewhere. Based on what he learned from the Knight Inlet experiment data, D'Asaro has been able to pick out solibore events in old data.

Predicting changes in circulation

The ability to predict accurately dramatic changes in littoral circulation is important to the safe conduct of military and civilian operations. Thanks to the richness and multidimensionality of the Knight Inlet data set, predictive models of changes in stratified flow in general and of solibores in particular should improve in accuracy. Because the improved models are based on a better understanding of the physics of the oceanic processes, they will allow extension into areas where data are sparse. ■



Eric D'Asaro

The three vessels used in the experiment.

Space-Based Views of the World's Great Ice Sheets

The lands of Greenland and Antarctica are cloaked by the world's great ice sheets. If global warming were to trigger an ungrounding of large portions of the sheets, which store nearly three-quarters of the Earth's fresh water, sea level could rise several meters worldwide within a century. Populous low-lying countries would be severely disrupted, and there would be social, economic, and political consequences for the entire world.

Many questions remain

The possibility of catastrophic collapse of the West Antarctic Ice Sheet was a hotly debated topic among climatologists and glaciologists in the late '70s and early '80s. Most glaciologists today agree that there is no evidence to indicate such a collapse is imminent.

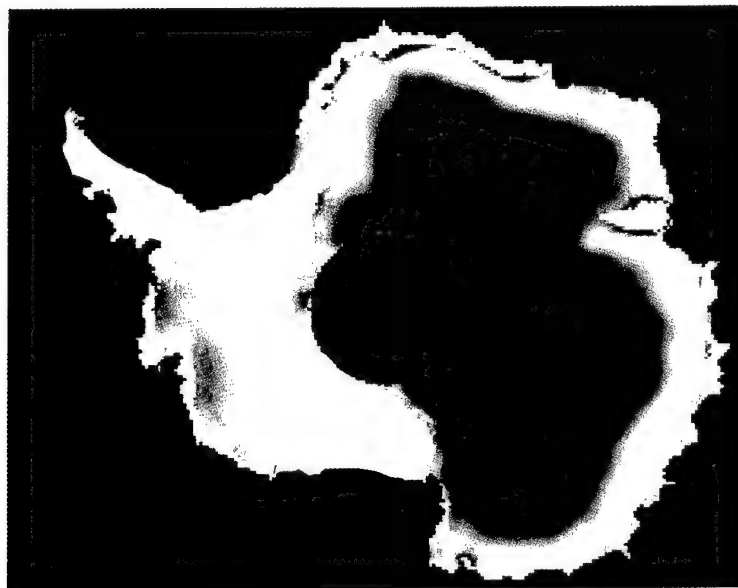
However, there is little information regarding ice-sheet behavior, primarily because of the inhospitable conditions for ground-based data collection. Several scientific questions regarding ice-sheet response to changes in climate remain to be answered:

- What are the current patterns of temperature and snow accumulation on the ice sheets?
- How would those patterns change as global climate changes?
- How would the ice sheets respond to changes in climate and would sea level rise precipitously?

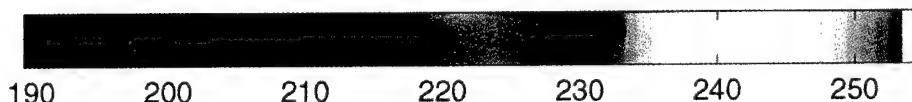
The data that will answer these questions are becoming available, thanks to better remote sensing techniques, such as space-based radar observations, and improved interpreta-

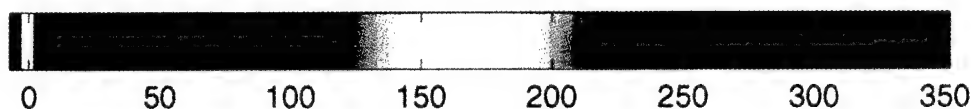
tion methods. APL Research Scientist Dale P. Winebrenner is contributing to these improvements by developing satellite-based methods for measuring the parameters that influence ice-sheet behavior—mean annual surface temperature, snow accumulation rates, topography, and flow. Tying these measurements of present-day ice sheets to the sheets' climatic history is essential to answering the key questions about behavior in a changing global climate.

As a specialist in scattering theory, Winebrenner, of the Laboratory's Polar Science Center, understands the physics of how electromagnetic waves, such as radar waves, interact with random, inhomogeneous natural materials such as ice. When an electromagnetic wave collides with ice, the behavior of the wave as it bounces off can reveal something of the material's qualities. His work has implications beyond Earth, for remote sensing techniques that work here may be applicable to other planetary bodies, such as the polar ice caps of Mars.



Map of decadal-scale mean surface temperatures (in degrees Kelvin) on Antarctica, as estimated from Scanning Multichannel Microwave Radiometer observations. Areas that may have melted within the past few decades are deleted (and appear white) because the physics of emission from those areas differs from that for dry firn, invalidating the estimation procedure. The circular hole near the center is a region where no data were acquired.





Map of accumulation rate (in kilograms per square meter per year) as inferred from Scanning Multichannel Microwave Radiometer observations. Again, areas subject to surface melting have been deleted. Accumulation patterns are strongly tied to ice-sheet topography as well as temperature.

Mapping surface temperatures

Winebrenner first developed an improved understanding of how electromagnetic waves interact with firn (compact snow), and then used satellite microwave (4.5-cm wavelength) emission data to map mean annual surface temperatures in the dry snow zones in Antarctica. (These zones exclude locations that melt during the summer.) Ground-based data, where available, agree well with Winebrenner's satellite-based estimates.

To estimate snow accumulation rates for Antarctica, Winebrenner again used 4.5-cm wavelength emission data, this time to interpret snow structure below the surface. Based on this technique, which links variations in snow

density and layering to changes in accumulation rates, Winebrenner and APL Post-Doctoral Research Scientist Rob Arthern have constructed a snow-accumulation-rate map for Antarctica.

Measuring ice sheet motion

Although ice sheets are solid, they flow slowly under the stresses of accumulating ice and snow. Understanding their flow requires studying the topography of the ice and how it changes over time. Under Winebrenner's supervision, Ian Joughin (then an APL graduate student, he is now at the Jet Propulsion Laboratory) acquired Earth Remote Sensing Satellite data and, using a technique known as satellite radar interferometry, mapped topography

and ice flow on the Greenland ice sheet.

The technique, which has much in common with the use of radar to map motion across earthquake faults, combines three or more spaceborne interferometric synthetic aperture radar images taken from slightly different viewpoints. By calculating the phase changes in radar waves returning to the satellite from the ground, measurements of motion, and therefore ice flow, may be derived. Ice-sheet motion is closely related to ice-sheet topography.

Climate record in the ice cores

The spatial patterns of mean temperature and snow accumulation at the surface of the ice sheets and the dynamics of ice flow must be correlated with the history of climate change as recorded in the long cores of ice that scientists have collected from the ice sheets. This 120,000-year-long climate record is derived from analyzing gases trapped in the cores and from studying the patterns of ice layering. Accurate interpretation of the patterns requires an understanding of how the dynamics of ice sheets influences those layers. For example, layers thin as ice sheets flow.

Because the ice-core records can be correlated between different geographic locations on an ice sheet, they form a valuable record of global climate change. Paleoclimate variability on scales from tens to ten thousands of years can be deduced, important information when trying to discern whether the climate variability observed today is anthropogenic or natural. ■

The Underwater Sound of Rain

A hydrophone sits beneath the water surface and records the sounds of a summer thunderstorm passing overhead. The hissing of small raindrops hitting the water mingles with the gurgles and plops of larger drops. The bass tones of thunder are occasionally heard. This music of the underwater sounds of rain is being carefully recorded by APL Senior Oceanographer Jeffery Nystuen.

Supported by the National Science Foundation, Nystuen is developing a method that uses the underwater acoustic signal of rain to better understand rainfall as an oceanographic environmental variable. Rain is an important factor in a variety of air/sea exchanges and climatological processes, contributing to mixing in the upper layer of the oceans and possibly to gas exchange at the air/sea interface, affecting surface waves, and, during rain formation, releasing latent heat, energy

that is an important part of the heat budgets of the atmosphere and the oceans.

Although a large portion of total global rainfall occurs over the oceans, data are sparse because rainfall at sea is one of the most difficult environmental variables to measure. Satellites offer some rainfall information, but these sensors are uncalibrated because of the lack of surface data for validation. Nystuen's method, which uses the acoustic signature of rainfall at sea to measure rainfall rates, should help fill in these data gaps.

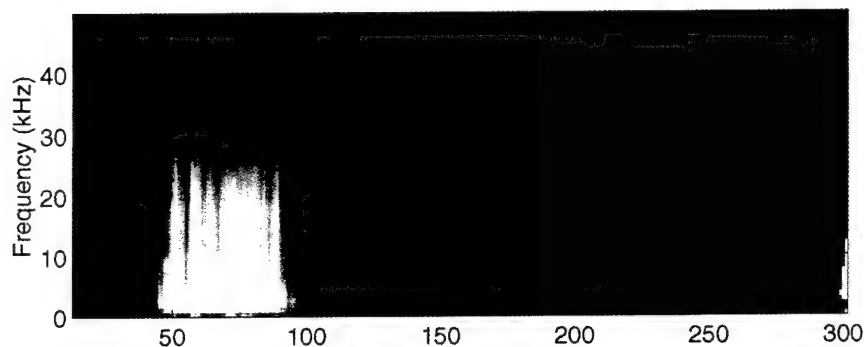
Raindrops, bubbles, and sound

When a raindrop hits the water, two basic mechanisms generate sound. One is the impact "slap," but a louder sound is often made when a bubble is trapped underwater during the splash. Sound is generated when inward momentum compresses the

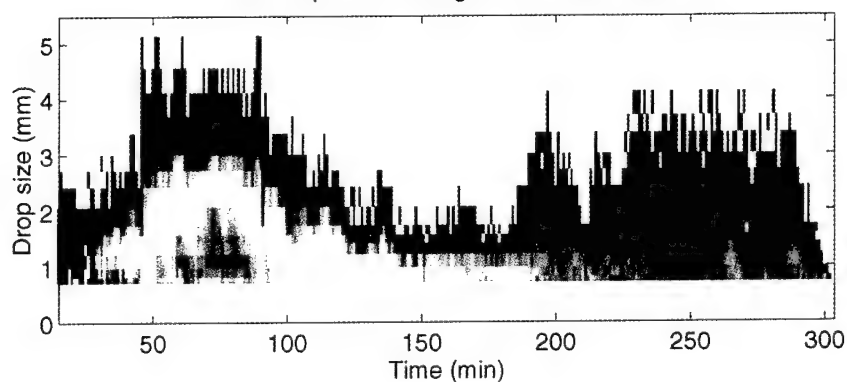
bubble until the pressure inside is higher than the ambient pressure. The bubble then expands outward, going slightly beyond equilibrium before it compresses again. As the bubble oscillates it generates a sound wave. A well-established relationship between bubble size and the frequency of sound generated means the bubble's acoustic signature can be used to interpret bubble size.

Raindrops range in size from 200 microns to over 5 millimeters in diameter, but only raindrops of certain sizes form bubbles and generate sound. When a small raindrop (one with a diameter between 0.7 and 1.2 mm), hits the water's surface, a small crater forms. If the surface tension pulls in the sides of the crater faster than the bottom comes up, a bubble is pinched off. This geometry is relatively uniform for all small raindrops and, because the size of the bubbles is also relatively uniform, a distinct 13–20 kHz sound, a "drizzle hiss," is produced. Medium-sized drops (those in the 1.2–2.0 mm range) have

Sound Field from a Thunderstorm



Raindrop Sizes during the Thunderstorm



The upper panel shows the temporal evolution of the underwater sound field during an intense thunderstorm. The lower panel shows the sizes of the associated raindrops. The main downpour starts at minute 50 and lasts until minute 100. The rainfall rates exceed 100 mm/hr. Many raindrops are present, including many very large ones. The sound field is very loud and includes components from under 1 kHz to over 50 kHz. When the downpour ends, an extended period of drizzle, with rainfall rates on the order of 1 mm/hr, begins and produces the distinctive sound of drizzle (a peak in the spectrum from 13–20 kHz). Late in the storm, large drops (over 2 mm diameter) are again present and lower frequencies in the sound spectrum are heard.

the wrong geometry for trapping bubbles and produce much less sound than small drops. On the other hand, large raindrops (2.0–5.0 mm) generate very violent splashes and produce both the loudest impact and the most sound from bubbles. Because a wide range of bubble sizes is generated by large raindrops, the sound spans a wide frequency range, from less than 1 kHz to over 50 kHz.

Distinctive acoustic signature

The combination of sounds from impacts and bubbles produces a distinctive underwater acoustic signature for rainstorms which can be recorded and analyzed. The pattern of a storm can be identified in the sequences of

sound. The big drops that tend to arrive at the beginning of a storm generate sound across a wide range of frequencies. Later in the storm, when only small raindrops are present, the sound consists of only the distinct “drizzle hiss.” Still later in this storm, a few large drops are present once again and the lower part of the sound spectrum fills in. By estimating the numbers of each drop size present, a quantitative estimate of rainfall can be obtained.

Sorting out the data

One of the challenges for Nystuen is to characterize the sounds of rainfall well enough to distinguish them from other noises in the sea—ships, breaking waves, or marine animals such as snap-

ping shrimp. The problem is complicated by the fact that algorithms developed at one location will not necessarily apply elsewhere. For example, will the algorithm developed for a shallow coastal area work in a deep-water location? Part of Nystuen’s search for the answer to this question is to find the commonalities in the data by using data sets from as many sources as possible. So far he has recorded the refrains of rain from freshwater lakes and canals and brackish mangrove-lined tidal ponds, and from the oceans, using coastal ocean buoys, deep-ocean moorings, and autonomous drifters. In the end, he hopes that his work will reveal new information about the global symphonies of rainfall patterns. ■

Medical Ultrasonics

Today’s parents of newborns often have a “picture” of their child before the baby is even born, thanks to images produced using ultrasound. Ultrasonic imaging, which uses high-frequency sound waves, has been in use for nearly five decades and has proven to be one of the safest diagnostic tools in medicine. The medical uses of ultrasound go beyond imaging, however, and work being done at APL promises applications in the therapeutic realms of reducing battlefield casualties and dissolving blood clots.

When ultrasound is delivered at intensities higher than those used for imaging, it can induce changes in human tissue through heating and mechanical effects. The thermal effects result when part of the ultrasound energy is absorbed by the tissue and converted to heat. The mechanical effects are caused by acoustic cavitation, a process whereby gas bubbles form and are

driven to violent collapse by ultrasound.

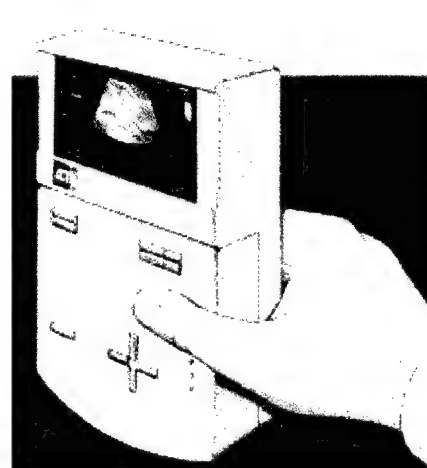
Scientists in APL’s Physical Acoustics Group are at the forefront of research in both the therapeutic and diagnostic applications of ultrasound. Led by Acoustics and Electromagnetics Department Chair Lawrence Crum, this research group is pursuing projects that include the development of a portable ultrasound device, an acoustic hemostasis device, enhanced drug delivery using ultrasound, and treatment for kidney stones.

Portable ultrasound device

Although diagnostic ultrasound is widely used in medical treatment facilities, the instrumentation’s 450-lb bulk requires that patients be brought to the machine, which excludes its use by emergency medical teams and forward combat casualty care units. Under development at APL, as part of a multidisciplinary university/industry collaboration, is the portable ultrasound device (PUD), a lightweight,

hand-held device that will provide the capabilities of the existing instrument.

In severe trauma, there is often a limited time after injury during which medical care is effective, the so-called “golden hour.” With the PUD, ultrasound imaging can be brought to the patient, whether the victim is an injured soldier on a battlefield or a civilian in a car accident on an interstate



An artist's conception of the hand-held portable ultrasound device.

Advanced Technology Laboratories

RESEARCH HIGHLIGHTS

highway, and emergency medical personnel can begin life-saving treatment within that crucial time frame. An ultrasound examination of a victim can reveal, for example, whether body organs are distorted from internal bleeding, where blood may be pooling in the abdomen, if blood is flowing through key vessels, and where shrapnel, bone, and debris have been driven into the body.

APL researchers are developing a simplified user interface for the PUD, in addition to investigating ultrasound techniques that specifically image foreign objects, such as shrapnel, that may not appear in x-ray images.

The development of this instrument is partially supported through the Technology Reinvestment Program (TRP) of the Defense Advanced Research Projects Agency. The TRP funds projects that have dual military and civilian applications and requires an industrial partner. Advanced Technology

Laboratories (ATL) of Bothell, Washington, is providing matching funding and engineering expertise. Other participants in this project are the University of Washington Departments of Radiology, Anesthesiology, and Bioengineering.

Acoustic hemostasis device

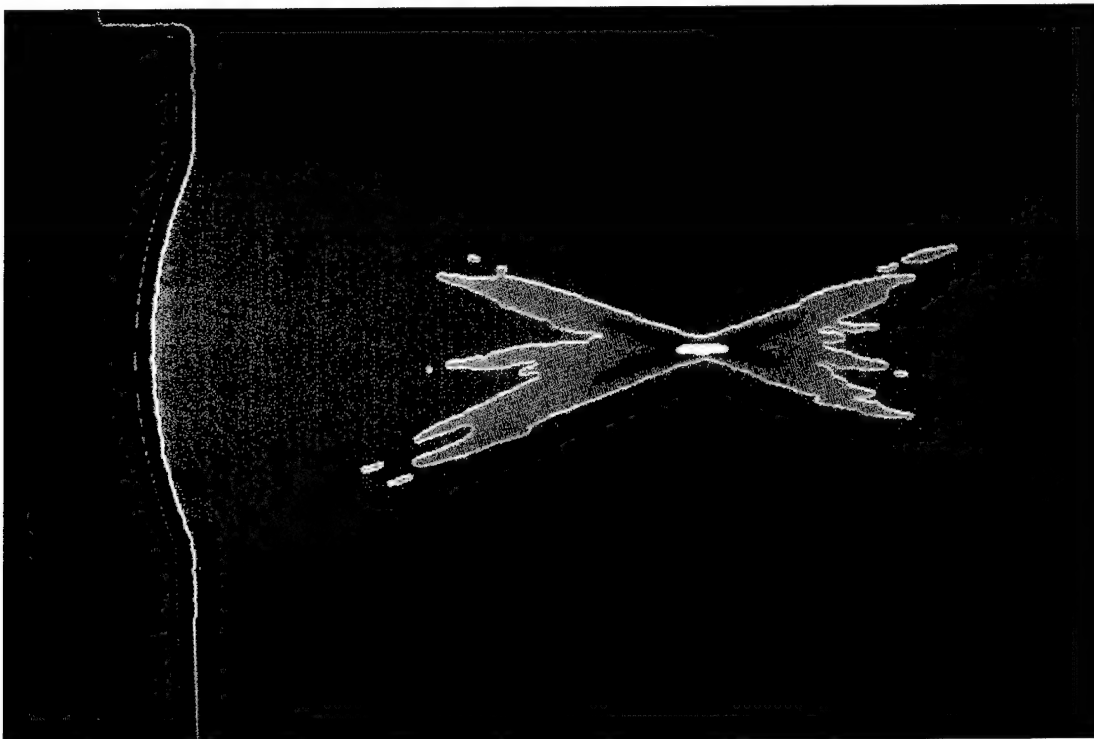
Once ultrasound has been used to diagnose and locate internal bleeding, it can also be used to halt the bleeding. Under development at APL is an acoustic hemostasis device that will induce internal blood coagulation at the hemorrhage site using high-intensity focused ultrasound. A small and well-defined focal zone allows for the precise delivery of acoustic energy that results in internal cauterization.

Up until now, treating internal bleeding has been a hospital procedure. The delay in transporting trauma victims to a facility may mean the difference between life and death. Use of a

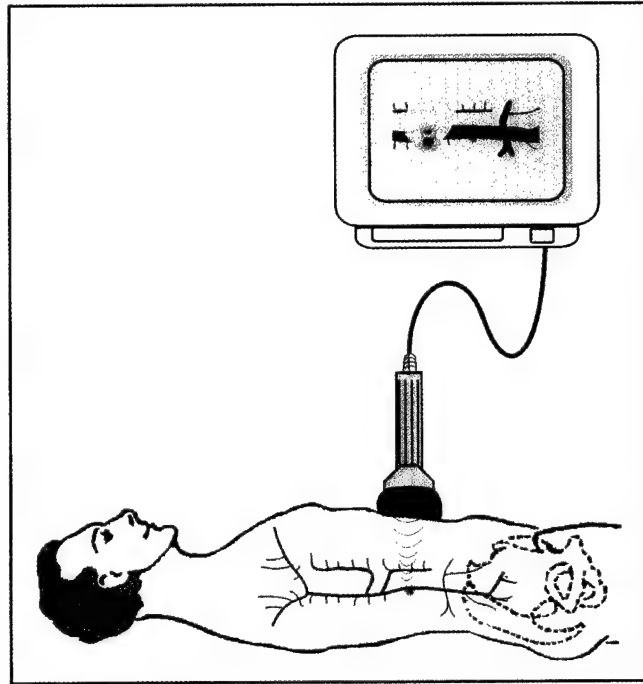
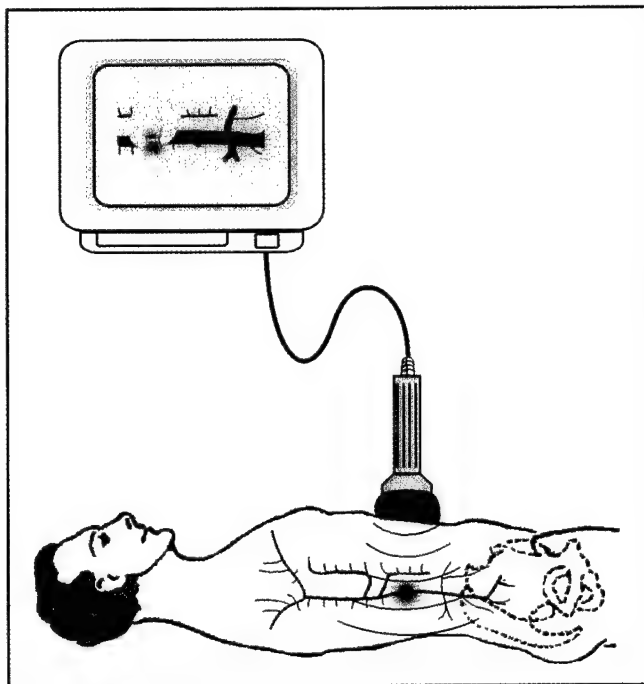
hand-held instrument for on-site treatment would dramatically improve the survival rate. Researchers envision eventually combining the portable ultrasound and the acoustic hemostasis devices.

The APL science and engineering team on this project is led by APL Senior Mathematician Pierre Mourad and Senior Electrical Engineer Peter Kaczowski. They are working on the *in vitro* and mathematical studies required to construct a prototype hemostasis instrument. How acoustic energy affects the body's natural clotting processes is being investigated in order to design methods that will maximize clot strength and longevity.

Also being studied is the formation of acoustic lesions brought on by the application of high-intensity focused ultrasound. The lesions, areas of tissue damaged by cavitation and/or protein denaturing, are surrounded by extremely sharp boundaries that are only



A false color image of the measured pattern of a focused transducer. Note the small and well-defined focal zone which will enable precise internal acoustic energy delivery and internal cauterization.



Dorothy Lowell

To prevent deaths from internal bleeding, a transducer is used in an imaging and Doppler mode to locate first the condition of internal bleeding and then the site of bleeding (left). The same transducer can then be used to apply high-intensity focused ultrasound to heat the site of bleeding, induce blood coagulation, and thus stem the bleeding (right).

6–10 cells thick, much thinner than what other technologies, including scalpels, can produce. The long-term hope is that with accurate targeting, acoustic lesions can be produced to accomplish some medical good, such as obliterating tumors or cauterizing internal hemorrhages.

This five-year multidisciplinary effort joins the Applied Physics Laboratory with the University of Washington's Departments of Radiology, Anesthesiology, Bioengineering, and Surgery.

Enhanced drug delivery using ultrasound

Ultrasound enhances the effectiveness of the so-called fibrinolytic drugs, such as streptokinase and urokinase, when used to treat blood clots. A new approach is to deliver the fibronolytic agent via a catheter inserted close to the

clot's location and to activate an ultrasound transducer located on the catheter tip. Experiments have shown that ultrasound significantly reduces the time needed for clot dissolution, which, in turn, has the potential for reducing the length of time a patient is hospitalized.

Just why ultrasound enhances the action of the drugs is unclear, but one theory is that cavitation initiated by the ultrasound helps the drug diffuse through the network of fibers formed during clotting. The medical acoustics research group is investigating this and other mechanisms by which ultrasound might enhance blood clot dissolution. Researchers are working closely with EKOS Corporation, a local company, to identify the optimal ultrasound exposure and drug delivery conditions for clot dissolution. This work is funded by the Washington Technol-

ogy Center and the Washington Research Foundation.

Extracorporeal shock wave lithotripsy

Research into using sonic shock waves to destroy kidney stones took a step forward at APL in 1996 with the acquisition of a lithotripter machine. Lithotripters are used in hospitals to break up kidney stones by a process known as extracorporeal shock wave lithotripsy. Although this process has been an accepted hospital procedure for more than ten years, just how the kidney stones disintegrate is still a matter of great debate. In a project sponsored by the National Institutes of Health, the lithotripter is being used to investigate the role of cavitation in kidney stone destruction. ■

Acoustic Shimmer Reveals Hydrothermal Vents

Just as waves of light passing through air over a hot road generate a shimmering mirage, so waves of sound from an acoustic transducer near the seafloor shimmer when passing through the hot and turbulent flows emitted from undersea hydrothermal vents. Thanks to a method developed at APL, this acoustic shimmer has proven useful in detecting and mapping water flow activity at these volcanic vents.

Undersea volcanoes

Hydrothermal vents occur along the mid-ocean ridges, a chain of undersea volcanic mountains that marks the line where two of the Earth's crustal plates are pushed apart as new seafloor is being formed when molten rock from the interior rises to the surface. As seawater

percolates down into the fissures of the mid-ocean ridges, it contacts emerging volcanic rock, is superheated, and rises rapidly, rushing back out through cracks in the ocean floor. Sometimes dramatic "smokers" occur—chimneys formed as the scalding water, laden with dissolved minerals, collides with the cold water at the seafloor and metal sulfides precipitate out into weird and fantastic shapes.

Exciting as these formations are, scientists suspect that the less dramatic, more diffuse flow of vent fluids from large fields of small cracks and fissures at the mid-ocean ridges may be the greater contributor of heat and chemicals to the world's oceans. Detecting and mapping diffuse flow, which is where APL's expertise in sonar imaging and acoustic shimmer has been ap-

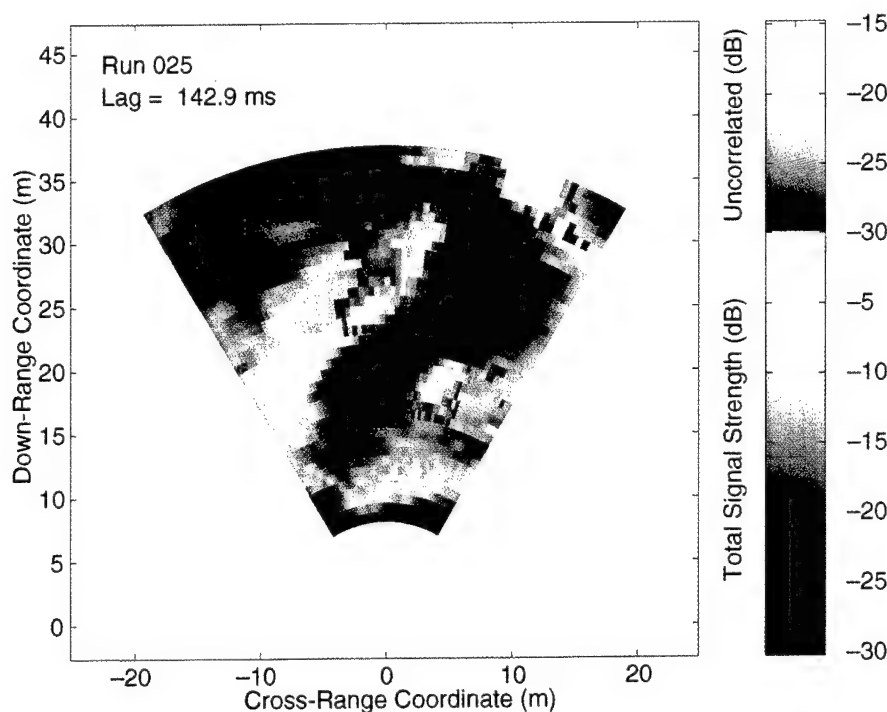


A "smoker," shown here, forms at undersea volcanic vents on the seafloor. (Photo courtesy of Russ McDuff.)

plied, is a first step toward understanding the magnitude of these vent field contributions.

Diving on the vents

Led by Principal Engineer Darrell Jackson, a three-person team from the Laboratory, in collaboration with Peter



Acoustic shimmer, generated when sound waves pass through the swirling hot water above a seafloor hydrothermal vent, is captured in this image. The red areas indicate diffuse flow.

Rona of Rutgers University, dove in the U.S. Navy's Deep Submergence Vehicle *Sea Cliff* on the Monolith hydrothermal vent located at 2250 meters depth on the Juan de Fuca Ridge 320 kilometers off the Oregon coast. The *Sea Cliff* was assisted by the Navy's Advanced Tethered Vehicle (ATV), a remotely operated vehicle equipped with television cameras, which mapped and scouted the area, placing marker beacons near vents to help guide the submersible to the right spot. Funding for the expedition was provided by the West Coast National Undersea Research Center of the National Oceanic and Atmospheric Administration's National Undersea Research Program.

The imaging system that proved its usefulness in identifying and mapping areas of diffuse flow near the vents was a Mesotech sonar mounted on the *Sea Cliff*, operating at a frequency of 330 kHz, and modified to record acoustic-wave phase information. After the outgoing ping from the transducer passed through the rising, hotter water of a diffuse flow, it hit an invariable surface, such as the seafloor, and was scattered back through the flow to be measured and recorded at a receiver. The swirling hot water caused random changes in sound speed and acted as a lens that altered the sound waves, much as light waves are changed and shimmer as they pass through the air over a hot road. The distinctive sonar image is due to the uncorrelated returns, or shimmer, of the sound waves from the seafloor. The red areas indicate diffuse flow near the Monolith hydrothermal vent.

Dramatic changes in water temperature

This method is related to one that was first developed at APL by Jackson and now-retired Senior Oceanographer George Dworksi to measure remotely water temperature at the seafloor as part of the Office of Naval Research STRESS experiment on sedi-



Darrell Jackson

Above: The U.S. Navy's Deep Submergence Vehicle Sea Cliff. Below: APL's Tim Wen (dark hair) is shown here in the Sea Cliff, preparing for a vent dive.



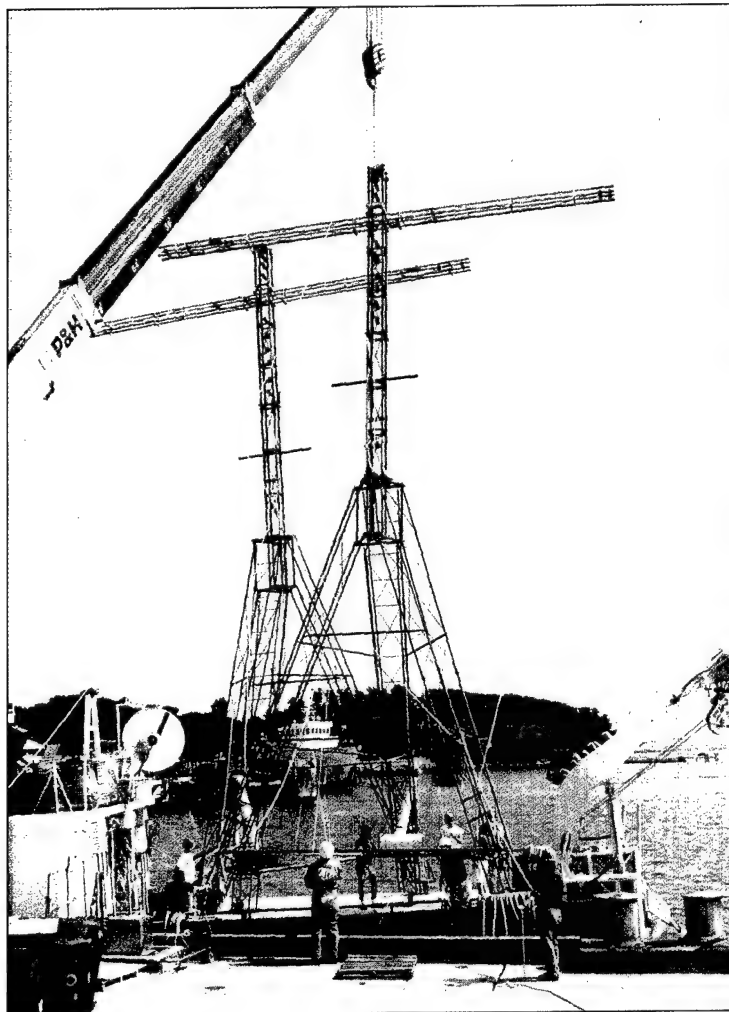
Darrell Jackson

ment transport on continental slopes and shelves. Because dramatic changes in water temperatures are reliable indicators of the presence of hydrothermal vents in the seafloor, applying this phase-coherent correlation technique to measuring vent flows was a natural step, and the *Sea Cliff* expedition proved the technique's success as a new acoustic method for detecting and delineating diffuse flow fields.

Future applications include using

the system to locate hydrothermal vents in addition to mapping diffuse flows. Despite the dramatic nature of smokers, they can be very difficult to find within the dark and vast reaches of the seafloor, a bit like looking for a needle in a haystack. The APL acoustic system that can remotely sense temperature offers a useful alternative to optical systems whose image quality suffers from the low-visibility conditions of the deep ocean. ■

Towers Beneath the Waves



Frank Henyey

The towers for the Synthetic Aperture Sonar experiment are loaded onto the fantail of the R/V Oceanus.

Two fifteen-meter high towers, designed and built at APL and equipped with acoustic transmitters and receivers, were lashed securely to the aft deck of the Research Vessel *Oceanus* as she headed south from Cape Cod in the summer of 1996. Several APL scientists and engineers were also on board, led by Senior Physicist Kevin Williams, experimental principal investigator in the ONR-funded Synthetic Aperture Sonar (SAS) experiment, and including APL Principal Physicist Frank Henyey, the modeling principal investigator for the project.

In order for the towers to fit on the fantail of the ship, their bases had to be carefully nested. Once at the experiment site southeast of Montauk Point, Long Island, the towers were rotated apart so they could be launched over the side using a crane and then lowered to the bottom of the ocean. Although there had been dockside skeptics who questioned the odds of success for such a tricky deployment, the launch, placement, and recovery of the towers went smoothly, and four days of high-quality acoustic data were successfully collected.

Effects on acoustic signals

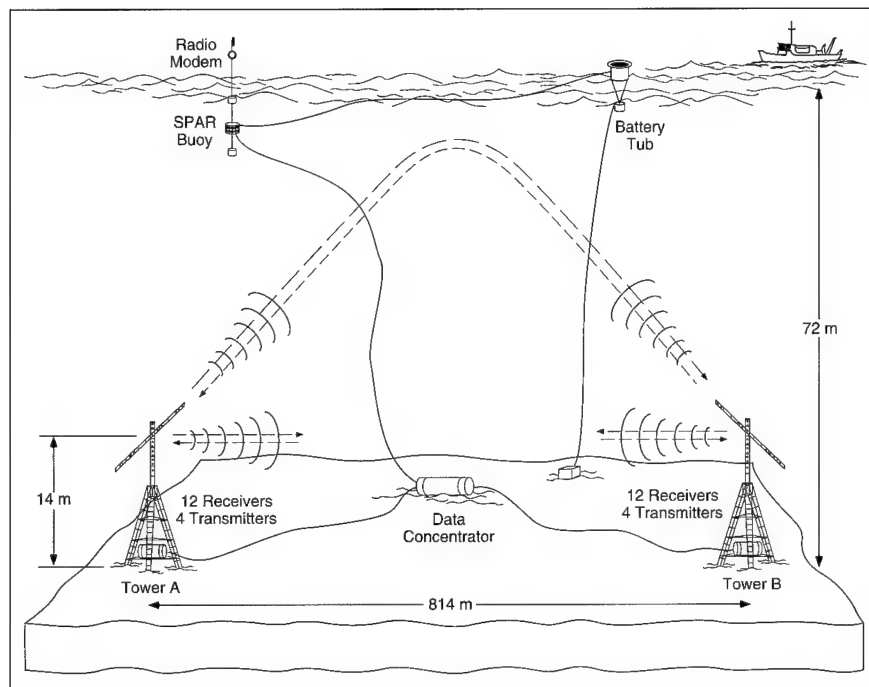
The goal of the SAS experiment was to collect data that would allow scientists to understand the effect of oceanographic conditions on the acoustic signals typically employed in the U.S. Navy's synthetic aperture sonar systems. The SAS experiment was one of many experiments undertaken at the site, all part of ONR's Coastal Mixing and Optics Program in which several institutions are participating.

In the absence of outside effects such as currents or salinity, ocean water is normally stratified by temperature differences—lighter, warmer water toward the top and denser, cooler water toward the bottom. However, wind-generated turbulence, currents, and internal waves often stir up these stratified waters in a complex way. Internal waves occur at the interface of warm and cooler layers of water, much as surface waves occur at the air-water interface. The water property changes brought about by internal wave mixing alter sound speed and sound paths, thus distorting signals sent and received by sonar systems.

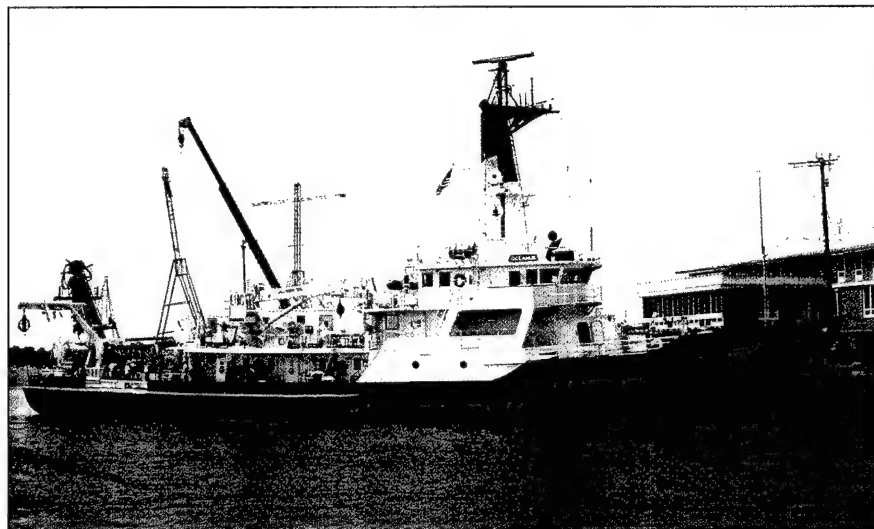
Synthetic aperture sonar

The Navy is developing synthetic aperture sonar to search for buried mines, often in shallow water near coastlines. This type of sonar processes the signals from a small number of hydrophones moving horizontally through the water to synthesize the equivalent of a long, fixed array, thus yielding the benefits of a large system in a small package. Synthetic aperture radars are used routinely in aircraft and satellites, but the application of synthetic aperture techniques to sonars is relatively new.

Ironically, the APL team used a fixed array of hydrophones to study how changes in water properties can affect the performance of synthetic aperture arrays. The height of the towers and the length of their 10-meter-long horizon-



Above: Schematic of the Synthetic Aperture Sonar (SAS) experiment. Below: After successful deployment and recovery, the SAS equipment is offloaded at the Woods Hole Oceanographic Institution's dock.



tal arms were determined from pre-experiment computer modeling using a combination of knowledge of the deep-ocean environment and historical data from the region. Signals of 6, 20, 75, and 129 kHz were transmitted from each tower and received on the opposite tower on six hydrophones spaced horizontally over each arm and another six spaced vertically down the

center line of each tower. Using the fixed-array towers allowed receiver locations to be precisely determined and enabled oceanographic effects to be separated out.

The tower-to-tower separation was chosen on-site so as to examine two different propagation paths: one path traveling upward before being refracted back to the other tower, the other trav-

eling just above the bottom, as shown in the illustration. To capture successfully these particular paths, the scientists took temperature measurements and calculated sound speed as a function of depth as they neared the site.

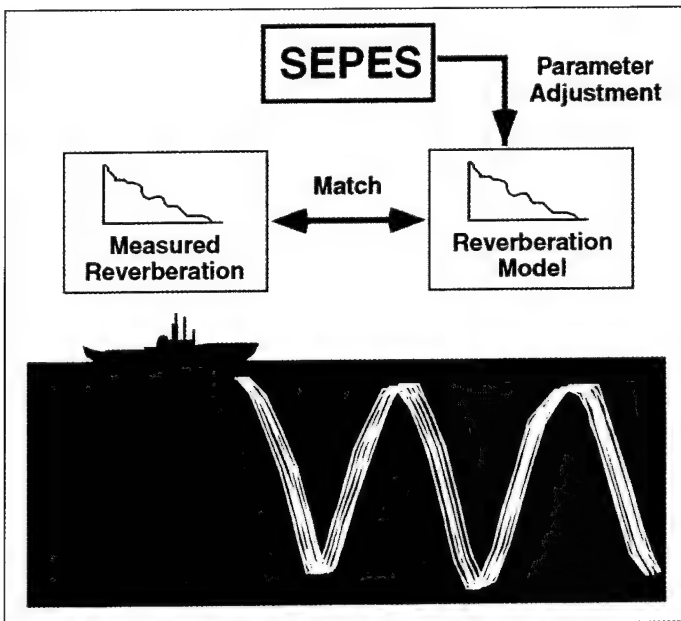
Acoustilinks electronics

The electronics used in the SAS data acquisition system were conceived by APL Principal Physicist Terry Ewart, who also took part in the experiment. Dubbed "Acoustilinks," the electronics have proven their value in widely varying environments, from on the ice in the Arctic to at sea in the North Pacific and North Atlantic. The versatility of Acoustilinks allows a variety of configurations and experiments, making the electronics a cost-effective field-experiment tool.

The initial analysis of SAS data has concentrated on the effect of internal waves along the lower path. As part of that analysis, the precise locations of the hydrophones on the tower arrays were extracted from the acoustic data. To the near disbelief of the experimentalists in the group, these acoustically derived positions showed an extremely high resolution of less than a millimeter. Direct measurements confirmed their accuracy. Such fidelity indicates that high-resolution measurements of the effects of internal waves and turbulence in the complicated waters of the near-shore environment may be possible.

Preliminary analysis of the experimental data has shown the collected data to be of high quality. Preliminary interpretations indicate that there are few effects from turbulence on acoustic propagation, but that there are definitely effects from internal waves. Furthermore, the results indicate that it should be possible, in some cases, to mitigate distortion to synthetic aperture sonar signals caused by internal waves. ■

Adapting Sonar to the Ocean Environment



The Sonar Environmental Parameters Estimation System matches model output with measured sonar data from the shallow-water, littoral environment.

designed for the shallow-water, littoral environment where many acoustic paths (multipaths) make such calculations extremely complex. The approach uses nonlinear optimization and analytical partial derivatives to automatically adjust the model parameters and match the model output to the measured sonar data. Once matched to the environment, the model can be used to make more accurate estimates of sonar effectiveness and to choose the best sonar mode of operation for that environment.

Estimated environmental parameters should be retained for future operations. Therefore, the APL team has developed an adaptive mesh technology that merges historical information stored in shipboard databases with environmental data gathered as a vessel transits an area. The system continually updates and improves environmental knowledge, giving at-sea commanders an important tactical advantage by increasing the chances of finding and identifying enemy submarines.

Improving sonar performance

Funded by the Office of Naval Research, the technology has been applied to problems as far ranging as reverberation from torpedoes (for the Naval Undersea Warfare Center) to low-frequency active sonar systems (for the Program Executive Office, Air Anti-Submarine Warfare). Thus far, the SEpes program has focused on the problem of extracting environmental parameters from acoustic data taken in the field, as well as from synthetic data. Applying what has been learned about the environment to the problem of improving sonar performance is the next step. The ultimate goal of the SEpes team, led by Senior Engineer Gregory Anderson, is to design a sonar system that not only senses the environment and updates the onboard database, but also adjusts sonar position, frequency, beam tilt, and other parameters to optimize performance. ■

The familiar point-and-shoot cameras automatically sense light levels and respond by adjusting shutter speed, aperture opening, and focus. With hardly a thought from the photographer about the environmental factors that might affect the quality of the image, these self-adapting cameras allow the user to easily create photographs that accurately represent the scene within the viewfinder at the time the shutter snapped open.

The Sonar Environmental Parameters Estimation System (SEpes) project under way at APL takes some of these same concepts and applies them to sonar operation in the highly complex acoustic environment of the ocean. Although there is much that acousticians understand about how ocean properties affect the propagation of sound underwater, this knowledge remains to be incorporated into sonar systems to help achieve the best performance possible and, like the camera, to present an accurate picture of what is in the "viewfinder."

Using a self-contained set of databanking and analysis software tools, SEpes collects and analyzes reverberation data from a ship's acoustic sensors. When the ship's sonar sends out a ping, the sound waves travel away from the ship, generally diminishing in intensity as they spread out through the water and are absorbed by the water itself or are scattered from objects in their path. When the sound hits an interface, such as the seafloor, some acoustic waves are sent back, like an echo in a canyon, while others are scattered in different directions.

Inferring environmental conditions

When the sound-speed structure in the water and bathymetry are known, environmental conditions, such as sea-surface acoustic properties, seafloor properties, and even scattering of sound waves by oceanic animals, may be inferred from sonar reverberation using acoustic models. While inferring environmental conditions from acoustic data is not new, the APL approach is

The Laboratory continues to explore ways to expand its contribution to the University's educational mission. Our primary means of supporting the University's and the Navy's educational goals is supervision of graduate student research. Currently some 27 staff members hold faculty appointments, a requirement for graduate student supervision. Although the number of graduate students has fallen slightly over the past two years, reflecting national trends, the program remains healthy, with graduate students constituting an integral part of the APL research program. With the University of Washington's renewed emphasis on undergraduate education, we are working with the Dean of the College of Ocean and Fishery Sciences to define a greater role in this important area.

In 1995, APL instituted a new undergraduate assistantship program to help confirm women and minority students in their choice of an engineering or science career and to train well-qualified candidates for future openings on the APL staff. APL's initial experience with the assistantship has been very positive. (See Student Profiles section.)

For many years, the Laboratory has offered a graduate fellowship to encourage outstanding scientific and engineering staff members in their pursuit of advanced degrees. In 1996, APL initiated an undergraduate fellowship to assist nontechnical APL employees in completing their bachelor degrees. Available to staff members who have already achieved junior class status, the fellowship pays tuition at the University of Washington for up to eight quarters.

APL has devoted a portion of its investment funding for

a number of years to programs that support education in grades K-12. Outreach to the K-12 community takes several forms—visits by APL staff members to schools, visits by students and teachers to APL, and summer fellowships for teachers. APL has become a regular participant in the University's annual Math Day, when secondary-school students are invited to the University to learn about some of the unusual ways in which mathematics is employed. APL is one of several field trip sites the students can choose from; typical topics for discussion might be using underwater sound to measure the ocean's temperature or the engineering challenge in developing a new oceanographic instrument.

The Laboratory also hosts visits from individual schools and groups. Classes from Lakes High School in Tacoma, Evergreen Junior High, and Natches High School, as well as students enrolled in the Upward Bound Program, visited APL to learn more about what it takes to do research.

After a one-year hiatus, Summer Teacher Fellowships were awarded in 1996 to Mark Lutzenhiser and Kathryn Lynda Sattler-Boudreau, who spent the summer at APL working as part of research teams. Mark, a high-school teacher from Issaquah, worked with the Physical Acoustics Group in designing instrumentation. Kathy, a middle-school science teacher, also in Issaquah, assisted with the development of the Puget Sound CD-ROM.

With the development of the Puget Sound CD-ROM, designed specifically as a teaching resource for science teachers, the Laboratory has entered a new area of research which could lead to additional contributions to education. ■

Advanced Degrees Awarded to APL Students & Staff

<i>Lynn Ailes-Sengers, Ph.D., 1996</i>	<i>Wendy Meiring, Ph.D., 1995</i>
<i>Theresa Beech, M.S., 1996</i>	<i>John Moe, Ph.D., 1996</i>
<i>Nicholas Beer, M.S., 1996</i>	<i>Sookhong Moon, Ph.D., 1995</i>
<i>Keith Brainerd, Ph.D., 1995</i>	<i>Dave Myers, M.S., 1995</i>
<i>Adam Calabrese, Ph.D., 1995</i>	<i>Carlos Rivera, Ph.D., 1995</i>
<i>Tamre Cardoso, M.S., 1996</i>	<i>Roy Schiff, M.S., 1996</i>
<i>Sean Cordry, Ph.D., 1995</i>	<i>Jeffrey Schindall, Ph.D., 1995</i>
<i>Troy Gilliland, M.S., 1996</i>	<i>Thomas Siderius, Ph.D., 1996</i>
<i>Steven Hare, Ph.D., 1996</i>	<i>James Turner, M.S., 1995</i>
<i>Eric Hirst, Ph.D., 1996</i>	<i>Danny Walsh, Ph.D., 1996</i>
<i>Ian Joughin, Ph.D., 1995</i>	<i>Yanling Yu, Ph.D., 1996</i>
<i>Christopher May, Ph.D., 1996</i>	<i>Lisa Zurk, Ph.D., 1995</i>

STUDENT PROFILES

Valerie Peyton, whose studies were partially supported by an APL Undergraduate Assistantship for Women and Minorities, graduated in June 1997 with a B.S. in Physics and a B.A. in Slavic Languages and Literature: Russian. Initially, that seemed a bad choice. After receiving a NASA Space Grant scholarship her freshman year and being selected to participate in the NASA Space Grant Undergraduate Research Program, she found she loved Russian and hated physics. But she decided to persevere for another year. Now she is a graduate student in geophysics at Yale and says, "It's so much fun!"



Dorothy Lowell

Valerie Peyton

Peyton credits much of that fun to her advisor, Principal Physicist Bob Odom of the Acoustics and Electromagnetics Department. For two years, they worked together on modeling the propagation and diffusion of acoustic waves in the shallow ocean, a project that required Peyton to apply or learn concepts from partial differential equations, linear algebra, stochastic processes, and continuum mechanics. "Valerie's understanding, enthusiasm, and performance during the last two years have been truly outstanding," says Odom. "She is able to apply what she has learned in her mathematics and physics courses to problems much more complicated than what she has seen in the classroom."

Peyton had to program a huge equation, which she couldn't understand. She spent her first few months at APL reading papers and books and "learning more than I've learned in any class in that short amount of time." She wrote the equation on her board, and after staring at it every day for 6 months, she thought, "Now I understand what's going on. This piece means this, and that piece means that."

Peyton's program solves for the diffusivity function that describes how acoustic energy spreads out in a random, lay-

ered medium with specified physical and statistical properties. The medium properties are stored in a file specifying the type of layers (water, sand, gravel, etc.) and their depth and the type of input signal and its frequency. Another program calculates the stresses and strains induced in the medium by the acoustic signal. Peyton's program then computes the diffusivity function from the stresses, strains, and some assumed statistical properties of the medium.

In April 1997, Peyton presented her work at a poster session sponsored by the Council on Undergraduate Research in Washington, DC, one of only 52 students from 37 states so honored.

Peyton applied to graduate programs in geophysics at the UW, Princeton, Harvard, and Yale and was accepted by all four. "It was a difficult choice," she says, but "I felt at home and comfortable in the department at Yale." It was also no small inducement that she would be working on the Kamchatka Peninsula in the Russian Far East, where she would join a group representing four disciplines (fluid dynamics, volcanology, seismology, and structural geology) investigating just how the Pacific Plate, which is subducting under the peninsula, produces volcanism.

Some of her physics professors claim that by going into geophysics she's forsaking physics. Peyton doesn't agree. "There's so much physics there!" she exclaims. "So much math. It's beautiful stuff."

When **Fritz Stahr** (Ocean Physics Department) decided to pursue an advanced degree in oceanography "because it was something I had loved when I was much younger," he picked the University of Washington because, he says, "the UW had both the School of Oceanography, which offered a good general education in oceanography, and APL, which had a well-integrated science and ocean engineering group."

While at APL, Stahr, who spent 10 years as a mechanical engineer making instruments for ophthalmologists and optometrists, has become the de facto advisor for principal investigators who want to incorporate optical instruments into their equipment. He has also helped in the development of the towed transport meter. As Stahr's advisor, APL Principal Oceanographer Tom Sanford, notes, "Fritz never met an activity he didn't want to be a part of."

During his first year at the Laboratory, Stahr participated in a cruise to the Blake Outer Ridge in the Bahamas. He intended to add optical instrumentation to APL's Absolute Velocity Profiler and a transmissometer to the conductivity-temperature-depth profiler. The optical results would then be cross checked against transmissivity data and water samples to examine sediment transport on the ridge, work that he hoped might lead to a Master's degree. But his modified optical instrument did not work, and the error in the filter system used to check the water samples was several times



Fritz Stahr

the signal he was seeking. As Stahr puts it, "It was a very useful lesson in experimental oceanography for someone coming from an engineering company, where most of the experiments are considerably more controlled than when dealing with the real world."

Stahr is now using a data set collected during that same cruise to the Blake Outer Ridge in his dissertation work to analyze the dynamics and transport of the Deep Western Boundary Current, which makes a U-turn around the ridge at a depth of about 4000 meters. The dynamics of the current are of interest to physical oceanographers, and the amount of water being transported is of interest to climate modelers as an indicator of the global climate. Some computer models predict that the current will diminish by a factor of 2 in the next 100 years because of the increase in carbon dioxide in the atmosphere. The current has been studied before, but the data gathered on its transport have been very divergent. "The APL cruise was probably the most accurate short-term survey of the place so far," says Stahr, and should provide good baseline data for comparison with the model predictions.

When Stahr finishes his dissertation 1998, he plans to get a post-doc somewhere in the Northwest, or perhaps try some teaching. "We're learning a lot in a very short period of time," he notes, "and we have things happening to the planet that we've never seen before. Natural scientists—geoscientists, oceanographers—will be needed to teach students what we're learning about the planet system."

Yanling Yu (Polar Science Center) is accustomed to struggle. Born in China, she lived through some of the toughest times there, including the Cultural Revolution. Despite the odds, she became a researcher at Academia

Dorothy Lowell

Sinica, a major oceanographic research facility in Qingdao, where she studied El Niño and large-scale air-sea interaction. When the UW research vessel *Thomas G. Thompson* came to Qingdao, she worked on a joint project with Richard Sternberg of the UW School of Oceanography. Subsequently, she investigated coming to the U.S. to further her studies. After three years of red tape, she was accepted at the UW, where she obtained an M.S. degree with Sternberg. Her Master's project was a study of turbulence in breaking waves in a near-shore environment.

Her M.S. completed, Yu decided to go back to her primary interest: air-sea interaction and climate change. But this time, she added ice to her cup of tea and started doctoral research supervised by Principal Research Scientist Drew Rothrock of APL's Polar Science Center. Her Ph.D. project was determining ice thickness from surface temperatures observed by satellites, which many people doubted could be done. She started by comparing the surface temperatures observed by advanced very high resolution radiometers (AVHRRs) on board earth-orbiting satellites with those measured in the Arctic by drifting buoys and at manned ice stations. Her study showed that AVHRR temperatures—derived from a single channel during the cold season in the central Arctic—are accurate to about 1°C. Based on this finding, she developed an algorithm that combines a thermodynamic ice model with satellite-derived surface temperatures to estimate the thickness and distribution of thin ice (less than one meter) in the Arctic.



Rex Johnson

Yanling Yu

STUDENT PROFILES

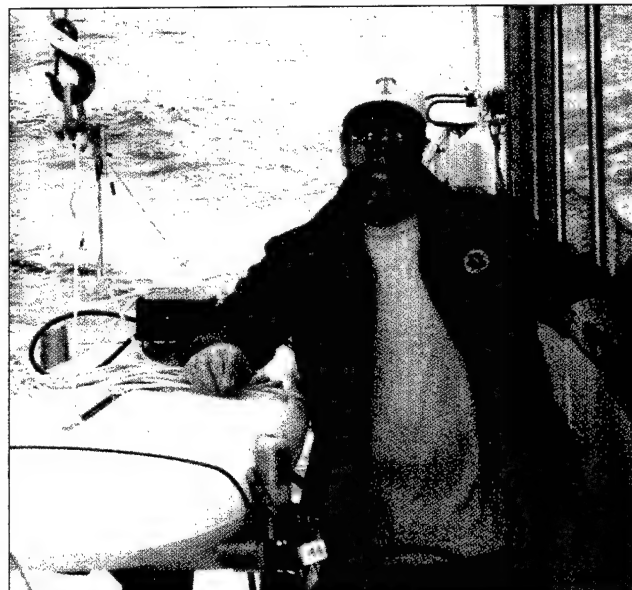
Comparing the model results with ice-thickness measurements made from submarines and upward-looking sonars, Yu demonstrated that AVHRR can resolve spatial and temporal variations in the thickness of thin ice. This finding provides a way to monitor thin ice in the Arctic over a large scale and has potential in climate study because thin ice plays a major role in both the dynamics and thermodynamics of the polar environment. Although thin ice accounts for only about 10% of the total ice, it represents about 70% of the total ice production, 90% of the total salt flux, and 50% of the total turbulent heat exchange with the atmosphere. In particular, salt flux from Arctic continental shelves is believed to influence substantially the Arctic halocline ventilation.

Yu completed her Ph.D. degree in June 1996 and is now working with Rothrock on related projects and writing proposals to pursue her own interests, such as improving her algorithm for estimating thin ice and applying the method to climate study. Yu enjoys the challenge of doing research. "Research is like solving mysteries all the time," she says. "You define a problem, you solve the problem, and you keep finding more interesting ideas."

Originally from Boston, **Christopher Zappa** (Acoustics and Electromagnetics Department) obtained a B.S. in Mechanical Engineering at Columbia University in New York City, where he quickly shed his distinctive accent. He then transferred to the UW to pursue an M.S. in Civil Engineering. In the fall of 1992, Senior Oceanographer Andy Jessup of APL offered Zappa a position at the Laboratory. Subsequently, Jessup became a member of Zappa's Master's committee, gradually taking over more and more responsibility as his advisor.

Zappa completed his M.S. in 1994 and will obtain a Ph.D. in Civil Engineering in the summer of 1999. His research involves infrared measurements in a wave tank to examine microscale wave breaking as a mechanism, or process, that would enhance air-sea gas exchange. The infrared imagery will be used to quantify the microscale wave breaking in order to determine changes in the gas exchange, which cannot be measured directly. Once Zappa's laboratory measurements have established "ground truth" data, it should be possible to model the process and check the model with field experiments—experiments Zappa would like to pursue as a postdoc.

Zappa's initial work at the Laboratory was supported by an APL fellowship. In September 1996, he was awarded a fellowship by Cambridge University, England, to attend the intensive, two-week summer school on geophysical and en-



Andrew Jessup

Christopher Zappa

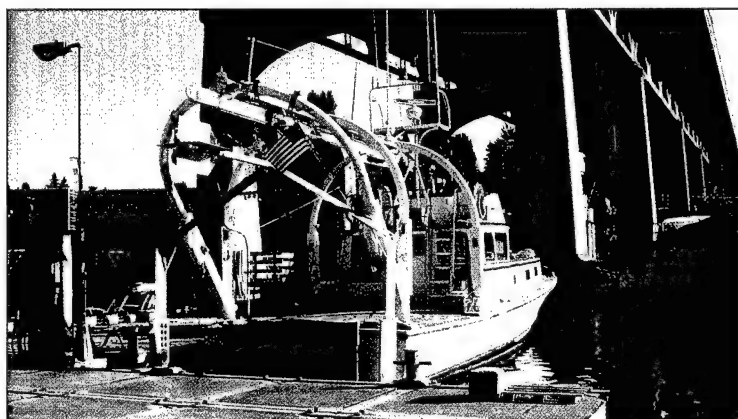
vironmental fluid dynamics conducted by the Cambridge Department of Applied Mathematics and Theoretical Physics. "I received independent feedback that he admirably represented APL and the USA in this very prestigious and demanding setting," Jessup notes.

Cambridge was but one of Zappa's excursions. In 1993, he had primary responsibility for ship-based measurements during an experiment off the coast of Oregon in which an infrared imager mounted in a blimp and a thermistor array towed from a ship were used to study changes in near-surface temperature due to breaking waves, fronts, and slicks. In 1994, Zappa and Jessup conducted an experiment at the Canada Centre for Inland Waters, during which they first observed an infrared signature of microscale wave breaking. Later, in September 1995, Zappa observed microscale wave breaking in the field from the research vessel *FLIP*. At the time, *FLIP* was moored off the Oregon coast as part of a large, multi-institutional experiment, one perhaps best remembered for the researchers' harrowing escape when the mooring shifted. "A number of the scientists on the cruise commented that they were very impressed with Zappa's capabilities and professionalism," says Jessup. Subsequently, in April 1996, Zappa handled all the logistics for a three-week cruise on a NOAA ship out of Miami.

Zappa "has developed into a mature, thoughtful, and careful researcher," according to Jessup, "with a keen interest in making connections with other fields by developing a broad perspective." ■

APL Graduate Students with Their Research Topics and Faculty Advisors

Lynn Ailes-Sengers	Ice-Surface Wave Scattering	D. Winebrenner	Jody Klymak	Mixing & Hydraulics	M. Gregg
John Allen	Mass Transfer in Pulsating Bubbles	R. Roy	Jennifer MacKinnon	Mixing in Coastal Regions	M. Gregg
Oleg Babko	Sea-Ice Motion Data from Satellites	D. Rothrock	Garfield Mellema	Post-Critical, Sub-Bottom Penetration	T. Ewart
Tony Beesley	Arctic Climate Modeling	R. Moritz	Miguel Nathwani	Solibore Analysis	F. Henyey
Richard Brocksomith	Predation on Salmon Smolts	G. Swartzman	Dung Nguy	Modeling Sea-Surface Waves	P. Dahl
David Caccia	Fractals in Ecology	G. Swartzman	Minkyu Park	Shallow-Water Acoustic Propagation	J. Mercer, R. Odom
Bill Constantine	Biomedical Time-Series Analysis	D. Percival	Tyrone Porter	Acoustic Hemostasis	L. Crum
Keith Curtis	Acoustic Oceanography	B. Howe	Mike Prinz	Wave Dynamics	A. Jessup
Geoffrey Dairiki	Langmuir Circulation	E. D'Asaro	John Rockway	Acoustic Tomography Applications in the Electrical Power Industry	R. Porter
Patricia Dell'Arciprete	Pollock Spatial Distribution	G. Swartzman	Tammarian Rogers	Acoustic Hemostasis	L. Crum
Martin Dorn	Modeling Fishing Processes	G. Swartzman	Kingshuk Roy	Image Analysis	D. Percival
James Girton	Deep-Ocean Overflow Dynamics	T. Sanford	Darin Soukup	Low-Frequency Sound Propagation	R. Odom
David Groves	Freshwater Balance in the Arctic Ocean	D. Rothrock	Fritz Stahr	Deep-Ocean Currents	T. Sanford
Ibrahim Hallaj	Beam Steering Using Acoustic Arrays	R. Porter	Elizabeth Steffen	Mixed-Layer Dynamics	E. D'Asaro
Tim Hammond	Fish School Classification	G. Swartzman	Jack Turnock	Animal Abundance; Fisheries Data Display; Spatial Analysis	G. Swartzman
Dan Hayes	Ice-Ocean Interaction	J. Morison	Danny Walsh	Fish Schools	G. Swartzman
Michael Heeley	Maximizing R&D Productivity	G. Swartzman	Chris Walter	Ocean Acoustic Tomography	J. Mercer, B. Howe
Christopher Jones	Acoustic Oceanography	D. Jackson	Brandon Whitcher	Wavelet-Based Statistical Analysis	D. Percival
George Kapodistrias	Acoustic Scattering from Artificial Bubble Clouds	P. Dahl	David Winkel	Mixing & Turbulence	M. Gregg
			Christopher Zappa	Gas Transfer Using Infrared Imagery	A. Jessup



The R/V Miller at the APL dock.

James Luby

HONORS, VISITORS & EVENTS

1995

The Excellence Award for Outstanding Performance from the Fixed Distributed Systems Office, Space and Naval Warfare Systems Command, was presented to Colin Sandwith. • Lisa Zurk, a Polar Science Center graduate student, received the Young Scientist Award from the International Union of Radio Sciences at a symposium in St. Petersburg, Russia. • Bill Bendiner was recognized as the volunteer of the year (1994) by the Pride Foundation. • For the second consecutive year, Paul Aguilar received the EOD Mobile Unit 17 Reserve Sailor of the Year Award. • Dan Rouseff was made a Senior Member of the Institute of Electrical and Electronic Engineers. • The Acoustical Society of America elected Eric Thorsos as a Fellow for "significant contributions to the theory of acoustic scattering." • Graduate Student Chris Jones was awarded the American Defense Preparedness Association Fellowship.

Andy Jessup was selected for the College of Ocean and Fishery Sciences' Research Faculty Award. • Ron Roy was honored by the College of Ocean and Fishery Sciences with the Distinguished Research Award. • The College of Ocean and Fishery Sciences' Distinguished Service Award went to Kelley Knickerbocker. • Ed Gough, returning from his assignment as Science Advisor to Commander, Sixth Fleet, received a commendation from Vice Admiral Pilling for superior service. • The American Defense Preparedness Association recognized Darrell Jackson's many contributions to acoustics research by presenting him with the Bronze Medal at the Association's October meeting.



Andy Jessup, shown here on board the USLTA airship participating in the Blimp/Microwave-Infrared Measurements Program off the Oregon coast, was featured as the "way cool scientist" on an episode of the PBS "Bill Nye the Science Guy" show.

Captain Jim Durham, Commander SUBGROUP ONE, a former student of APL Director Bob Spindel, visited in January. • Rear Admiral Richard D. Williams III, Program Executive Officer for Mine Warfare, toured the Laboratory in April. • Visiting in May was Rear Admiral Henry Herrera, Commander SUBGROUP NINE. • Anatoliy Ivakin of the Andreev Acoustics Institute in Moscow, Russia, was a visiting scientist working with Darrell Jackson. • Collaborating with Larry Crum on ultrasound studies were visiting Russian scientists Vera Khokhlova and Oleg A. Sapozhnikov of the Department of Physics, Moscow State University. • Officers from the USS *Pargo*, which hosted PSC scientists during the first submarine arctic



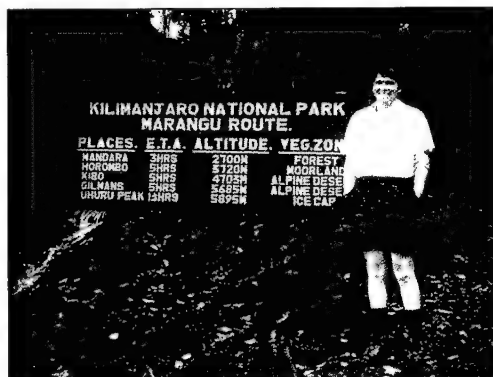
The American Institute for Public Service and The Seattle Post-Intelligencer honored Bob Miyamoto with the Jefferson Award, which is given for extraordinary contributions by volunteer workers. Miyamoto was cited for his work with the Washington State Chapter of the National Neurofibromatosis Foundation. Shown here are Bob, with daughter Tamra, wife Deanna, and U.S. Senator Patty Murray (center).

science cruise, visited the Laboratory in February as guests of Jamie Morison. • A familiarization tour of APL facilities and research programs was given to Captain Dave Anderson, SPAWAR PMW181 Fixed Surveillance Systems Major Program Manager. • Rear Admiral Paul Gaffney, Chief of Naval Research and Commander, Naval Meteorology and Oceanography Command, visited as a member of the ATOC oversight panel. • In residence for six months and collaborating with Mike Gregg was Takeshi Matsuno of the University of Nagasaki, Nagasaki, Japan. • Program Managers from many Navy Warfare Centers and Laboratories met at APL for the annual meeting of the Naval Science Assistance Program.

During a visit in August, Rear Admiral George Davis, Oceanographer of the Navy, was briefed on the Lab's oceanography research. • Captain Paul Taylor, Commanding Officer of the Trident Training Facility at the Naval Submarine Base, Bangor, visited in January. • Captain Bruce Dyer of the Marine Systems Technology Office at DARPA received briefings on the Laboratory's capabilities during a visit in February. • Visiting in May to explore collaborative opportunities with the UW and other academic institutions were Captain Robert Plante, Commanding Officer of the Fleet Numerical Meteorology and Oceanography Center, and Captain Deiter Rudolph, Commanding Officer of the Naval Oceanographic Office. • APL and the School of Oceanography hosted a team of scientists from the Office of Naval Research in June for the biennial ocean sciences program review. • In October, Charles Wicke, Science Advisor to Commander Mine Warfare Command, toured the Laboratory. ■

1996

Jim Luby was commended by Program Executive Officer (Undersea Warfare) for his contributions as a member of the Surface Ship Torpedo Defense Anti-Torpedo Torpedo Study Team. • Roger Anderson was guest of the week on "Blue Ice: Focus on Antarctica," a World Wide Web-based interactive resource for elementary school children. • College of Ocean and Fishery Sciences' Research Faculty Fellowships were awarded to Peter Kaczowski and John Wettlaufer. • Director's Awards were made to Bob Bratager and Terry Mahony.



Kate Bader climbed Africa's Mt. Kilimanjaro.

Tom Sanford was elected to Fellowship in the American Geophysical Union. • Members of the Acoustical Society of America elected Larry Crum to serve as President in 1997-98. • The College of Ocean and Fishery Sciences' Distinguished Service Award was presented to Bob Bratager. • For his contributions in ocean engineering, John Hart received the American Defense Preparedness Association's Bronze Medal. • Le Olson was commended by the University for his service on the UW Diving Control Board.

The Polar Science Center hosted a number of international visitors during 1996. • Tore and Birgette Furevik from the University of Bergen spent the year at the Polar Science Center, working with Knut Aagaard and Dale Winebrenner, respectively. • Jens Meincke from the University of Hamburg collabo-



Sing-along at the APL holiday gathering.



Vladimir Pavlov of the Arctic and Antarctic Research Institute, St. Petersburg, Russia, spent two periods at APL working with Jamie Morison on arctic pollution. Shown here are (l. to r., standing) Morison and Pavlov with Roger Andersen (seated).

rated with Knut Aagaard. • John Nye of the University of Bristol, UK, visited John Wettlaufer. • Christian Metzler, University of Bern, made an extended visit while collaborating with Dale Winebrenner. • M. Grae Worster, Cambridge University, was hosted by John Wettlaufer. • Jinping Zhao and Zhichang Guo, both of the Institute of Oceanology, National Academy of Sciences in China, spent several months at APL working with Jamie Morison. • Bert Semtner and Wieslaw Maslowski of the Naval Postgraduate School visited Knut Aagaard.



APL Innovation Awards were presented to (l. to r.) Greg Anderson, Jim Luby, Jim Osse, Dan Stearns, Ron Roy, Ed Gough, and Larry Crum.

The Physical Acoustics Group hosted visits by Suk Wang Yoon, Sung Kyun Kwan University, Republic of Korea, Oleg Rudenko, Chair of the Department of Acoustics at Moscow State University, and Gail Ter Haar of the Royal Marsden NHS Trust, United Kingdom.

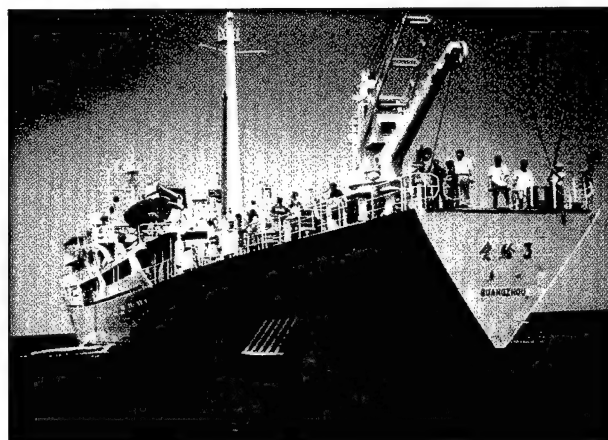
Captain Charles Munns of the Navy's Strategic Studies Group (SSG) visited to discuss the SSG mission and to learn of APL's capabilities. • The Puget Sound CD-ROM was demonstrated to William Graham, Director of the National Sea Grant Office. • Tim Douglas, Program Executive Officer, Undersea Warfare, visited in August. ■

FIELD OPERATIONS

<i>Location</i>	<i>Program</i>	<i>Activity</i>	<i>Leader</i>	<i>Date</i>
Pillar Pt. Air Force Station, CA	ATOC	Install electronics	Mercer/Spindel	Jan-Feb '95
Puget Sound	CLAMSS	Install mines & test sonar	Kaczkowski	Jan-Jul '95
Key West	CBBL	Seafloor acoustic scattering	Williams/Jackson	Feb '95
Key West	TEVA	Surface acoustic scattering	Dahl	Feb '95
San Diego	Marine Boundary Layer	Breaking wave measurements	Gregg/Miller	Feb '95
Arctic Ocean	Nuclear Contaminants	Hydrography/recover moorings	Aagaard	Mar-Apr '95
Greenland Sea	SCICEX	Environmental & climate studies	Steele/Aagaard	Mar-May '95
Skagit Bay	Vorticity Sensor	Vorticity measurements	Sanford	May '95
Lake Washington	CLAMSS	Test sonar	Kaczkowski	May-Jun '95
Greece	NATO FORACS	Certification	Mercer	Jun '95
Indian Head, MD	PEMI	UXO detection demo	Kaczkowski	Jul '95
Orcas Island	BAMS	Seafloor acoustic scattering	Jackson/Williams	Aug '95
Arctic Ocean	Nuclear Contaminants	Deploy moorings	Aagaard	Aug-Sep '95
Beaufort Sea	Arctic Ocean Monitoring	Hydrography/ deploy & recover moorings	Aagaard	Aug-Sep '95
Greenland Sea	Fram Strait Flux	Deploy & recover instruments	Aagaard	Aug-Sep '95
Off Oregon coast	NOAA COPE	Blimp/microwave & FLIP IR measurements	Plant/Jessup	Sep '95
Orcas Island, Puget Sound	CLAMSS	MCM sonar trials	Kaczkowski	Sep '95
Knight Inlet (BC)	Solibore	Study stratified flow dynamics in coastal waters	D'Asaro	Sep '95
Alpha Helix, Chukchi Sea	Western Arctic	Hydrography & moorings	Aagaard	Sep-Oct '95
Spring Beach, Puget Sound	CLAMSS	Install mine field & test sonar	Kaczkowski	Nov '95
Labrador Sea	Lagrangian Float	Deploy deep Lagrangian floats	D'Asaro	Jan '96
Bahamas	NATO FORACS	Certification	Mercer/Spindel	Jan '96
Panama City, Florida	Diver-Held Sonar, Mod 1	Test/evaluate	Belcher	Feb '96
Burlington, Ontario	CCIW 96	Microwave scattering	Plant	Apr '96
Lincoln Sea	Iceshelf	Deploy ALDV	Hart/Osse	Apr '96
Annapolis, Maryland	Acoustic, Barnacle Imaging System	Test/evaluate	Belcher	Apr '96
Gulf of Mexico	FSLE	IR study of gas transfer	Jessup	Apr '96

Russ Light (left) and Peter Dahl making final inspection of acoustic recording instrumentation to be placed in a subsurface mooring.

Below: View of the Chinese research vessel Shi Yan 3 standing by to recover one of APL's moorings.



Peter Dahl



<i>Location</i>	<i>Program</i>	<i>Activity</i>	<i>Leader</i>	<i>Date</i>
Off California coast	ATOC	Alternate source test	Mercer/Spindel	Jun-Jul '96
New England Shelf	Acoustic Coherence	Acoustic transmission experiment	Williams/Henyey	Aug '96
New England Shelf	Coastal Optics & Mixing	Measure shear & turbulence on the Continental Shelf	Gregg/Miller	Aug '96
Yellow Sea	Joint U.S.-China Experiment	Shallow-water acoustic propagation	Dahl/Spindel	Aug '96
Hawaii	IUSS IMP	Install front-end system	Mercer	Aug '96
Arctic Ocean	Nuclear Contaminants	Hydrography/recover moorings	Aagaard	Aug-Oct '96
Whidbey Island	Diver-Held Sonar, Mod 2	Test/evaluate	Belcher	Sep '96
Juan de Fuca Ridge	NOAA NURP	Sonar imaging of hydrothermal flows	Jackson	Sep '96
Fram Strait	Fram Strait Flux	Deploy & recover moorings	Aagaard	Sept '96
Beaufort Sea	Arctic Ocean Monitoring	Hydrography & moorings	Aagaard	Sept '96
Chesapeake Bay	NRL COPE	Airborne microwave measurements	Plant	Sep '96
Hawaii	ATOC	Install source	Mercer	Oct '96
Whidbey Island	IUSS IMP	Demo test	Mercer	Nov '96

FINANCES

APL's financial condition was strong through Federal Fiscal Years (FFY) 1995 and 1996. Grant and contract awards, at \$30.7M and \$27.8M, were slightly in excess of expenditures. Navy project work accounted for about 70% of the total.

The Navy's budget was reduced in FFY 95 and FFY 96, and we expect this trend to continue over the next few fiscal years. Precisely what this means in the long term to a university research and development laboratory such as APL remains uncertain. Given that the Laboratory retains talented researchers and a strong, diversified basic research and technology base, we are optimistic that APL will continue to receive significant federal research development grant and contract funds. In FFY 96, 62% of APL's funding was for basic research. This research remains a strength for the Laboratory.

The Laboratory's discretionary resources, derived mostly from contract fees, are approximately 4.2 % of total income.

The largest fraction of these funds is devoted to internal Independent Research and Development efforts, which are currently focused on new directions that build upon our Navy-related expertise. Other APL discretionary expenditures include graduate student support, staff fellowships, building improvements, and general-use equipment.

APL intends to continue to pursue opportunities with other government agencies and with industry. Our intent is twofold. First, we want to ensure that the Navy's considerable investment in APL continues to be applied to national technical needs. Second, during this period of military reduction and restructuring, we seek to preserve our ability to respond effectively to present and future Navy needs. We expect the Navy to remain our principal sponsor.

APL's Department of Defense grant and contract funding exceeds that of all other units of the University combined. The Laboratory's research budget is among the largest on campus. ■

SPONSOR	FFY 1995	FFY 1996
Office of the Chief of Naval Research	\$9,269,268	\$10,101,417
Naval Intelligence Center	7,286,000	5,762,000
Space and Naval Warfare Systems Command	1,360,603	1,884,566
Naval Sea Systems Command	2,174,299	1,115,000
Naval Surface Warfare Center	729,376	927,318
Naval Air Systems Command	330,000	262,000
Naval Explosives Ordnance Disposal	649,000	260,000
Naval Underwater Systems Command	282,366	178,000
Naval Research Laboratory	546,583	144,000
Other Navy	1,296,434	559,197
Advanced Research Projects Agency	1,966,450	1,361,912
National Science Foundation	1,813,282	1,245,560
National Aeronautics & Space Administration	1,695,484	1,370,505
National Oceanic & Atmospheric Administration	622,859	457,649
National Institutes of Health	138,124	330,039
Department of Energy		769,843
Other Non-Navy	570,801	1,081,509
Total Funding	\$30,730,929	\$27,810,515

Directorate

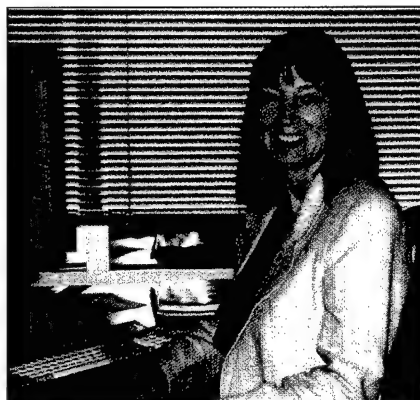
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Adj. Prof., Oceanography
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Assistant to the Director Vada Matthew

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 Engineer
 Kou-Ying Moravan • Senior Physicist
 Donald B. Percival • Senior Mathematician;
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 Mark W. Stoermer • Engineer
 Gordon L. Swartzman • Senior Engineer;
 Res. Prof., Fisheries
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 Daniel C. Walsh • Predoctoral Research
 Associate
 Joseph S. Wigton • Engineer

Ocean Engineering Department

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 A. Robert Doerr • Engineering Technician
 John B. Elliott • Engineer
 Lyle F. Gullings • Senior Field Engineer
 David G. Hoefke • Field Engineer
 Frederick W. Karig • Principal Engineer
 Harold A. Kolve • Principal Engineer
 Thomas W. Lehman • Oceanographer
 Russell D. Light • Senior Engineer
 Victor C. Lo • Senior Engineer
 Vernon W. Miller • Senior Engineer
 Larry D. Nielson • Field Engineer
 Michael A. Ohmart • Engineering Techni-
 cian
 Francis G. Olson • Field Engineer
 LeRoy O. Olson • Principal Engineer
 T. James Osse • Senior Engineer
 David L. Ramstad • Senior Engineer
 Robert L. Ruedisueli • Engineer
 Peter L. Sabin • Senior Field Engineer
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 Daniel A. Stearns • Field Engineer
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 David W. Van Ess • Senior Engineer
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 William P. Bendiner • Principal
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 A. John Black • Software Engineer
 John A. Blattenbauer • Engineer
 Clark A. Bodyfelt • Engineer
 Richard J. Broman • Field Engineer
 Kennon J. Conrad • Senior Engineer
 Stephanie Coulter • Senior Engineer
 Warren L. J. Fox • Engineer
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 William H. Hanot • Senior Engineer
 Benjamin M. Henwood • Senior Engineer
 Robert E. Johnson • Principal Engineer
 William A. Jump • Senior Engineer
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 Ronald R. Ryan • Principal Engineer
 Martin Siderius • Engineer
 Richard E. Stahl • Field Engineer
 Carol L. Stayner • Electronics Technician
 Marvin L. Streng • Principal Engineer
 Robert E. Van Note • Senior Field Engineer
 Ann Vanlandingham • Engineer

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 Allan G. Brookes, Jr. • Coordinator; Senior
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 Terrence M. Mahony • Engineer
 Hugh D. Nelson • Coordinator—Research
 Janet I. Olsonbaker • Coordinator—Research
 Colin H. Saari • Coordinator—Research
 Jennifer C. Clesceri • Office Assistant
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 Physical, Technical & Central Support
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Distributed Computing Services

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Ronald G. Gamble • Electronics Technician
Brian P. Kelly • Field Engineer
Larry C. Swan • Electronics Technician

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Priscilla T. Schneider • Library Specialist
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Richard B. Siegrist • Operator
Daniel A. Stearns • Operator

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Eshrat Shahrazad • Fiscal Technician
Susan L. Womack • Fiscal Technician

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Charlotte A. Boynton • Program
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Craig C. Conant • Office Assistant
Shannon M. Hickman • Office Assistant

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Michael R. Craig • Warehouse Worker

Travel

Faye L. Harman • Fiscal Specialist
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Management and Finance

Administration

Jackie S. Kendall • Administrator

Financial Management

Anne L. Clark • Administrator
Anthony J. Nice • Manager
Mariano B. Ballera, Jr. • Accountant
Gail M. Gilliland • Senior Accountant
Theodore J. Miller • Accountant
Sergei F. Schmidt • Accountant
Darcy L. Wohlhueter • Office Assistant

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Larry C. West • Manager

Grant & Contract Administration

Moir G. McCrory • Administrator

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Robert M. Bratager • Manager
Linda M. Marsh • Program Support
Supervisor

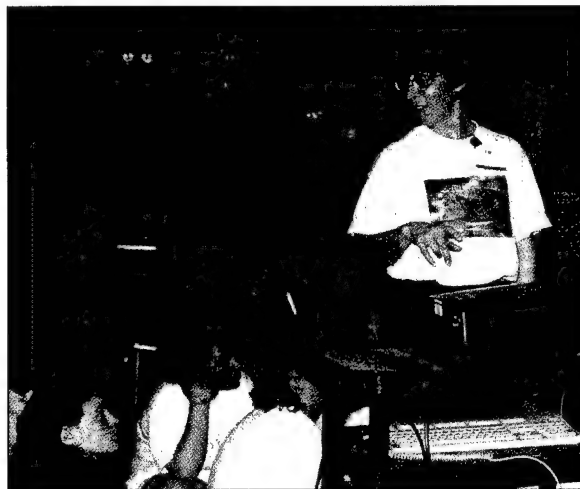
—personnel as of June 1997

In Memoriam

Clark H. Darnall, 1943–1997



Patricia M. Hardisty, 1944–1997



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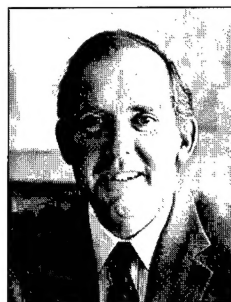
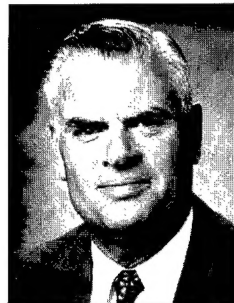
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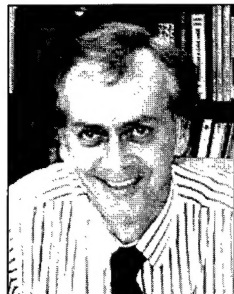
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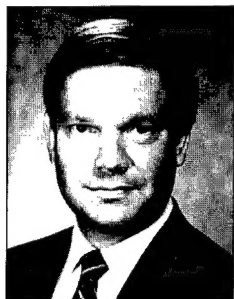
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